Materials & Methods

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SALT BATH TREATMENTS FOR METALS
MATERIALS & METHODS Manual No. 24

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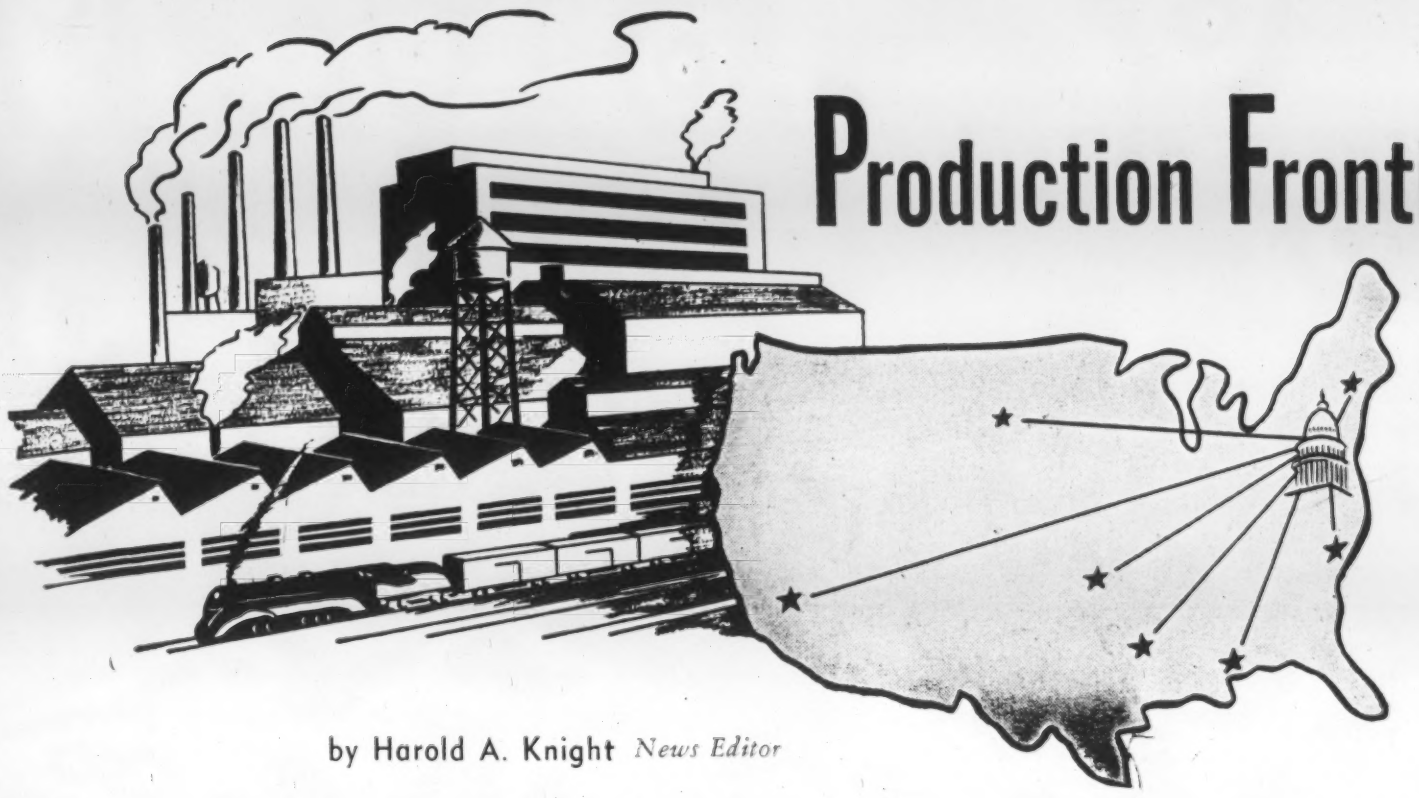


Production Frontiers

by Harold A. Knight *News Editor*

Green Light for Return of "Buyers' Market"

That-a-boy! That's the way to talk! Listen to this from James S. Knowlson, president and chairman, Stewart-Warner Corp.:

"A buyers' market, to any manufacturer operating on the simple theory that 'no one ever went broke giving people what they want' offers a challenge and opportunity not to be found in a sellers' market. Then, all of a company's experience and dexterity in creating wants through advertising and merchandising, meeting them through design and production efficiency, and harvesting the profit thus sown, through skillful selling, can best be coordinated. The company that is lulled by a false security of a sellers' market can too easily forget product perfection and the creation of new markets. Stewart-Warner has not been so lulled."

One hears optimism for the consumer on every hand. Even as this is written, for instance, we learn that prices of second-hand automobiles have dropped $100 to $300. Surely the great capacities and great techniques acquired during the war will soon bear fruit in the form of the tremendous production for which the American people are noted. We can't help but believe that relations between labor and management will be much more harmonious in 1947.

In his "Report to the President," John D. Small, when retiring from the Civilian Production Administration, stated that industrial production "for the last six months has climbed from one peacetime record to another." He pointed to all-time highs in the production of consumer durable goods, most of which are being produced at higher rates than before the war. As to building materials, in many cases output has multiplied three and four times since war's end.

Shortages which exist are of three major categories, stated Mr. Small: (1) from international supply problems which must be solved by particular techniques in each instance; (2) from lack of adequate plant capacities, which will be corrected if demand holds up; and (3) from a shortage of natural resources which can be corrected only by finding substitute materials or sources.

As for labor leaders who are continuously asking for higher wages, consider the Westinghouse advance financial report for 1946. Stated Gwilym A. Price, president: "We estimate that the operating loss for 1946 will amount to more than $50,000,000. This is a staggering loss considering that the company's total losses in the three worst years of the depression amounted to $21,196,040."

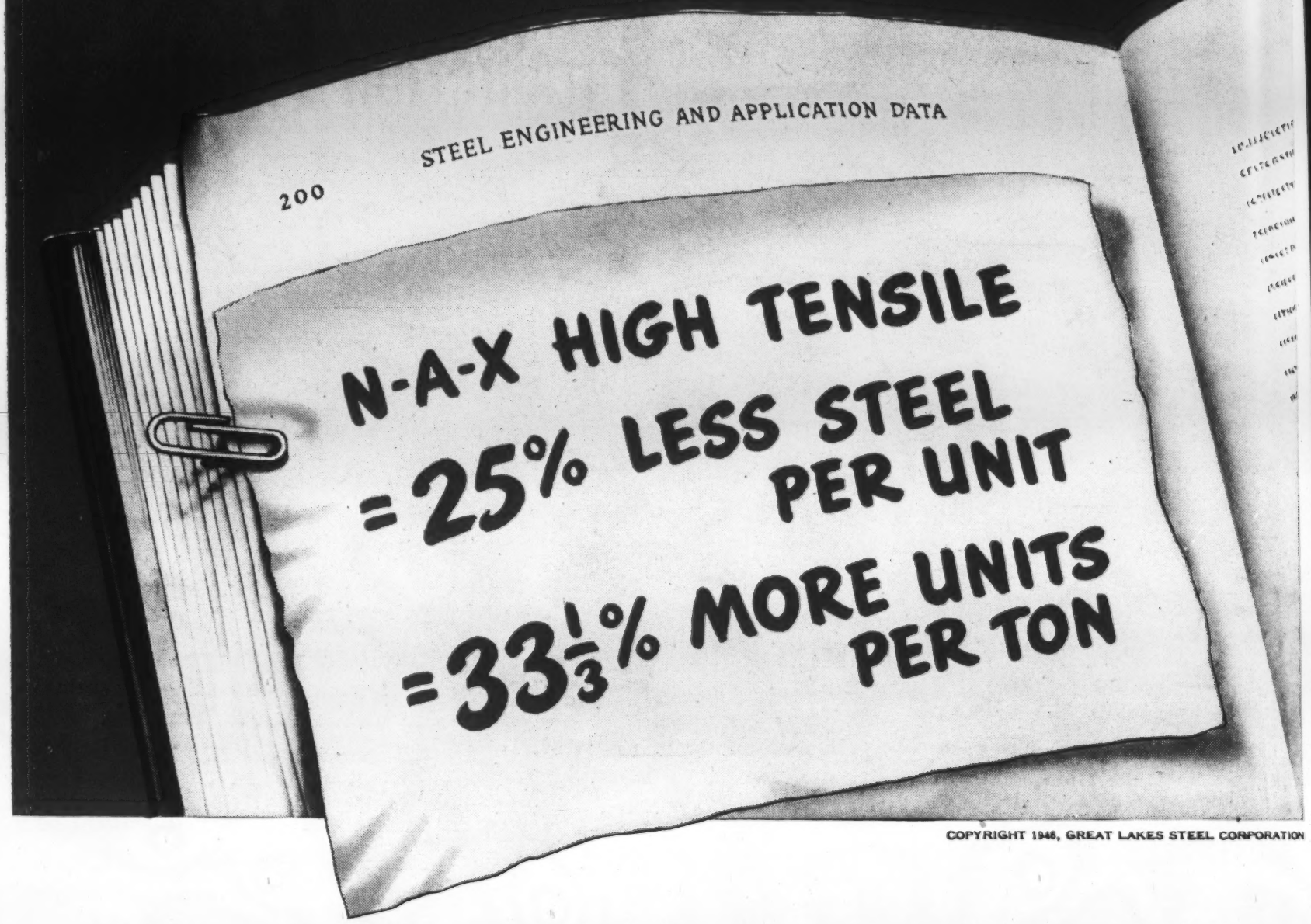
Listen, too, to Enders M. Voorhees, chairman, finance committee, U. S. Steel Corp.: "American industry is not in nearly as sound financial position as it is too often prone to think it is. This is complacency that is ominous. It is a common fallacy to suppose that war breeds prosperity. But this flies in the face of inner conviction and certain knowledge of the awful wastes of war in lives, wealth and resources. War breeds a fantasy of figures and the fantasy is too often mistaken for fact. War wrenches the economy as nothing else does; the economic changes wrought are of seismic proportions."

But let us end this economic dissertation on a more cheerful note. Let us heed the concluding paragraphs of an essay by Paul G. Hoffman, chairman, Committee for Economic Development, on "We Can Prevent 'That Next Big Bust'."

"In the last few years thoughtful studies have been given, by private and public agencies, to the problem of understanding our economy. It is the most hopeful sign, I think, of our times. Such researches can lead us to the truth that will light our common path.

"If we follow that light, we can make the new America even greater than the old. We have created the world's highest standard of living. In 25 years, granted peace, we can

THE NEW ARITHMETIC IN STEEL



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double that standard. This achievement will flow from our having the right knowledge and the right spirit, and it will give us an intellectual and spiritual as well as a material triumph."

German Powder Metal

During the war more metal powder was used in Germany than in all other countries engaged in the war. The Germans used more iron powder in a month than we produce in a year. German equipment involves the hot pressing method rather than the cold pressing method, which is more generally used in the United States.

So says Gregory J. Comstock, professor of powder metallurgy and director of research, Stevens Institute of Technology, Hoboken, N. J., who visited Germany in 1945 on a U. S. Government mission. Moreover, equipment for the manufacture of hard cemented carbides, brought from Germany, has been installed in a new building at Stevens. The 12 pieces of machinery and associated apparatus, weighing 100 tons, were used by the Germans to make armor piercing projectiles with hard cemented carbide cores which proved exceptionally effective against tanks.

The equipment is being loaned to Stevens by U. S. Ordnance for use on the Bureau of Ships research program, the results to be shared by the Army, Navy and industrial projects engaged in the development of heat resistant materials and high temperature alloys for jet propelled airplanes and rockets.

The more common method of making high heat resisting parts is by forging or casting, which limit the range of usable alloys. Powder metal parts may offer the real solution.

In the German hot pressing method the heat and pressure are applied simultaneously to the powdered metals, while in cold pressing the application of pressure at room temperature is followed by heat treatment. According to Prof. Comstock, the German process is not necessarily better than ours, but is at least different and warrants investigation.

The hard cemented carbide projectiles had been used by the Germans since the civil war in Spain. The British used such projectiles sparingly from the time of the attack on Rommel in Africa. The United States used them to a small extent after D Day. It is presumed that we used the carbides sparingly for projectile cores because we did not wish to shoot away our precious tungsten, needing that metal for what we considered more important uses.

Steven's study of the problem will be in the field of powder metallurgy with the German equipment. Massachusetts Institute of Technology will study the fusion metallurgy point of view, while Rensselaer Polytechnic Institute will explore the electric resistance sintering angle.

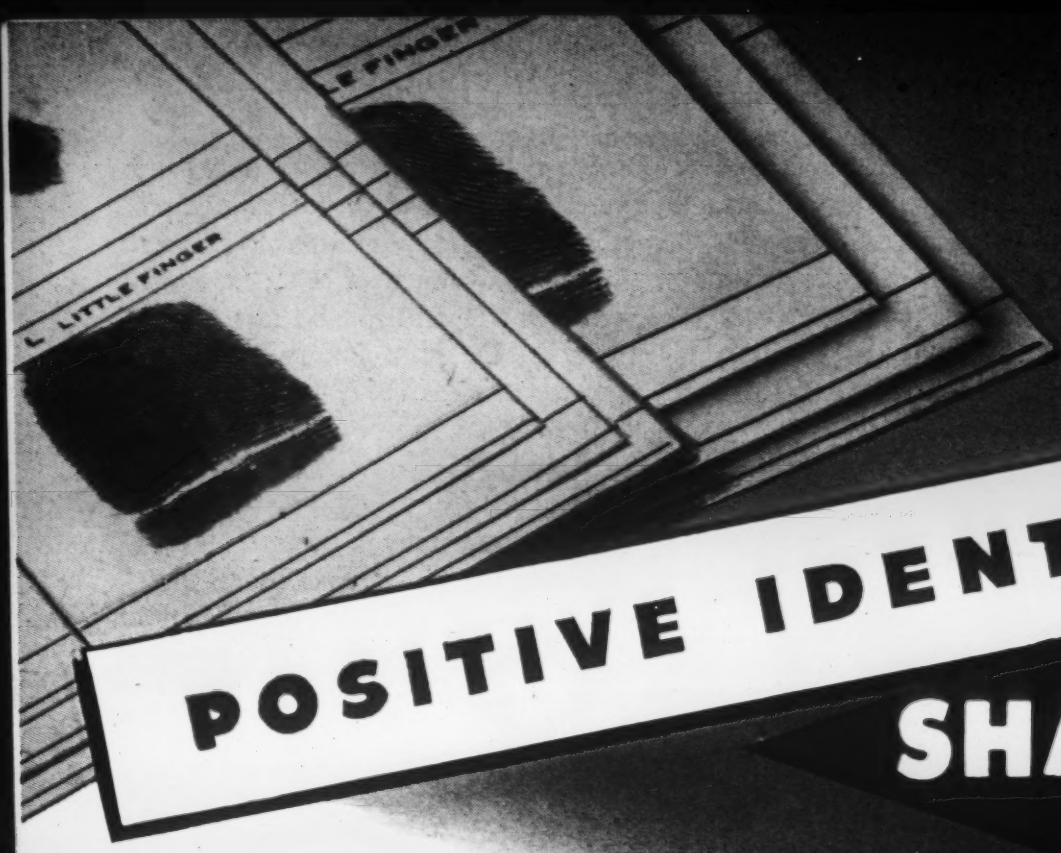
"Jones wants to go into some other section—he thinks he's been around the cutter too long!"

Philosophy of A Researcher

It would be well if every person who has made real contributions to man's progress sit down at his retirement from his life's work and jot down on paper his philosophies and pertinent discoveries for contemporary and future generations to ponder. In this way much of what is worth while in life will not be lost.

So has Dr. John Johnston, retiring director of research, U. S. Steel Corp., written the "Scientific Approach to Technical Problems." His advice is to "proceed from the known into the great unknown by a series of steps each supported by experiments that yield the same results, no matter who makes them or where they are made. The experiment need not be a new one; it may well have been made years ago, whence the advisability of studying the literature before proceeding far with any technical investigation."

The learned Dr. Johnston, who left Yale as head of the chemistry department to organize a research laboratory for U. S. Steel in 1928, states



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that the course of War II would have been different (to our sorrow) if it had not been for scientific knowledge gained almost entirely from research undertaken prior to the war to satisfy the curiosity of investigators, but with little thought to practical use.

Thus, examples are radar, the atomic bomb, blood plasma and penicillin—as well as his own laboratory's isothermal transformation diagrams, published before the war, which enabled war industry to get a maximum production and heat treatment of shells, bombs and many other ordnance items from the limited number of furnaces available quickly.

These transformation diagrams aided greatly in selecting steels which could be most readily heat treated in the emergency to obtain necessary combinations of qualities. Important, too, was our knowledge of how to interpret indications of magnetic tests, made by using equipment we had developed and applied to separate good from bad material when an immediate answer was imperative.

"If a group of eminent scientists had been asked a century ago to investigate the best method of illumination, the possibility of electric light would almost certainly not have appeared in their report. A solution of a problem may come in a way entirely different from what present practice would lead us to expect. Yet this possibility is no excuse for doing nothing about it, even though we see no clear way immediately ahead.

"In attacking a complex research problem one must make a thorough analysis of the entire situation to learn what it really is in contrast to what it seems to be. It is preferable to start with some simple hypothesis —no matter what, so long as it does not conflict with established scientific principles—and to plan experiments which will either confirm or contradict it. If the latter, be ready to abandon the first hypothesis and to formulate a new one.

"To abandon an idea is something which is not easy for anybody and impossible for many."

What a Designer Thinks About

"Good design is built in, not draped on. Good design grows more important every day as life becomes more and more highly mechanized." So wrote Harold Van Doren, of the design engineering firm of Van Doren, Nowland & Schladermundt, New York, in the *Saturday Evening Post* of Aug. 3.

"Before the war, design was all too often a matter of hunch and punch. Competition was fierce, production was going full blast, and deadlines seldom gave designers time to get to the bottom of a problem. You scrambled for your drawing board and rushed models to completion because a sales convention was scheduled for March. During the war, designers have had time for sound thinking, time to improve their own methods."

The author was commissioned to design bathrooms. A study revealed that the standard washstand is too low. As for the bathtub, it is used a third of the time for foot bathing and bathing of children, with little attempt to make these convenient. Safety for shower bathers has been almost completely ignored.

The author analyzed the postures people get into when in the tub, reaching for the soap, turning on the faucets, etc. It was found that controls should be within easy reach of the right hand, or about the middle of the tub. One end should be tapered to reduce water consumption. Sides should be reasonably high and a built-in footrest is advisable.

"We design the ideal, then work down from the ideal to the possible, trying to retain something of the ideal at every sacrifice," philosophizes the author.

"The same tub has to serve for a shower, which demands modifications from the mere sit-down tub. The ideal tub would have a heated backrest, but it's too expensive. One can't make the tub as deep as would be liked because of the cost of drawing steel. One can't place the controls in the middle, for the buyer must use old plumbing connections. Handrails to help get in and out are too expensive, though may be sold as an accessory.

"The ideal tub would have a real seat on the side for bathing children. The practical tub has a flat space on the side instead. In the ideal tub the glaze would be roughened in spots to prevent slipping in the shower, but the housewife would find cleaning it difficult.

"The net result of the study is a bathtub of unusual shape, completely different from anything made so far, yet fitting into standard architectural specifications, which allow 5 ft. for a medium tub. The final tub gives as much room as the next size larger, with a shower seat thrown in."

The author states that his firm has designed many machine tools, stamping presses and the like. "I don't think we have ever failed to make them more convenient and safer for the operator," he concludes.

Hitting on a whimsical note, the author has been called upon to design hog shavers. "Not that the hog cares," the author shrewdly reasons out loud, "but so the shaver will be easier for the farmer to handle, make less noise and, yes, look better in the catalog."

Why Paint Your Home?

One does not really need to paint wooden houses or any other wooden item merely to preserve it—painting mostly enhances its appearance. Fancy that! At least that is our interpretation from an interesting literature piece from *Silicate P's & Q's,* January, 1947, put out by the Philadelphia Quartz Co., Philadelphia 6.

They quote from Dr. F. L. Browne, Forest Products Laboratory, well-known authority on wood chemistry. In contrast with the cost of painting, he says, it would probably be cheaper to build our houses with inch-thick sidings and allow them to go unpainted since loss by weathering is such a slow process—roughly ¼ in. per century. Driving through the by-ways of New England one sometimes sees an unpainted weather-beaten house—beautiful, too!

Wood rots only through attack of organisms, usually where in contact with the earth, since the fungi require moisture for their life processes. Impregnation with creosote or other fungicides is needed.

Weathering, on the other hand, is a slow process of wearing away by alternate rapid shrinking and swelling of the fibre due to constant changes in moisture content. Paint films prevent such moisture changes in the surface layers of the wood and thereby protect the fibre from decay.

In fact, house painting did not become customary until about 200 years ago. A barber was expelled from the Massachusetts Bay Colony because he had painted his home. Such unseemly frivolity!

It's safe to assume that a barber didn't paint his poles like a stick of peppermint candy in those days either.

The MATERIALS OUTLOOK...

Aluminum: Best Bargain

Aluminum seems to have an increasing appeal because it is relatively the cheapest among the nonferrous metals and compares favorably economically with many grades of steel. It has already risen to second-ranking metal of peacetime industry, in terms of volume produced. Architectural and building applications have nosed out transportation as the largest outlet. One need not fear shortages, for 1947 production will be 1,260,000,000 lb. as against 836,000,000 lb. in 1946. Prices, lower by 25% since 1939, have kept stable, with minor exceptions, during the recent era of rising prices. Last year over 500,000 aluminum windows were made, to rise to over 2,000,000 this year. Aluminum producers will not deviate from the present 15c base price, not wishing to damage this golden era of aluminum expansion.

Some Hope for Tin Supply

Tin users will probably get all of that material they want sooner than some Government authorities have implied. Thus, CPA recently estimated "that production will not meet unrestricted demands for tin until 1949." Yet tin producing circles themselves—who ought to know—say that production will overtake demand at a much earlier date than that envisaged in official quarters. The present world stock of tin totals 140,000 tons, which is 80,000 tons over what was regarded as adequate in pre-war days. During the tin scarcity many substitutes were used, several of which will prove permanent. Prices have reached their peak.

Plenty of Helium Gas

Those who have recently taken up the use of helium gas, say for helium-shielded arc welding of light metals and stainless steel, can be assured of a steady supply for many years to come. We get that news direct from the nation's sole supplier, the Bureau of Mines. Without this assurance of good supply one might become alarmed because of the tremendous expansion in use. Thus, last October a new all-time record for sales to private users was established, at 1,367,880 cu. ft. Sales in 1947 will average over a million cu. ft. monthly. The development of a satisfactory method of welding aluminum with this gas has given its consumption a new impetus. The Bureau's four plants have annual production capacities of nearly 250,000,000 cu. ft.

Lead at Record High Price

When the price of lead rose to 13c per lb. early this year it reached an all-time high. One has to go back to 1917, when it sold at 12¼c, to find a comparable price, while the low in this generation was 3¾c in 1932. "But what goes up must come down" is the law of gravity and of market prices. In 1917 when it sold at 12¼c, it sold as cheaply as 5½c the same year. The 13½c price is just double the ceiling price—a pretty fast and severe advance.

Lucite Plating Barrels

Those who do metal plating by the tumbling method and who have been using rubber barrels should take note of a barrel made of du Pont's "Lucite" acrylic resin. Objects to be plated are held in a perforated container which is dipped and revolved in a vat. Remember how, with your hard rubber barrels, the work often caught on the ribs? Moreover, how the rubber sometimes became ionized, with plating forming on it? With the plastic this is eliminated.

Glass for Bearings, Etc.

Nonmetallic bearings have become numerous and varied, including those made of lignum vitae and fabric, plastics, and cemented carbide. Also, boron carbide and sapphire for bearing surfaces on instruments, gages, etc. Now we have glass-silicone bearings, with life six to 20 times that of metal bearings, lubricated with water or steam in addition to petroleum lubricants. Electrical equipment manufacturers might also explore new fibre glass-covered wire, cast directly into aluminum or other metal, thereby attaining a hermetic seal and indestructible resistance element.

Don't Overstock Copper

Forward looking buyers are stocking copper sparingly, keeping inventories small because a sizable drop in prices is not too far distant. Just as the stock market expert bases much of his judgment on history of values in the past, so does the skillful copper buyer study the record. Copper, at 19½c per lb., is now the highest since those over-inflated days of 1929 when it reached 24⅛c. The next year it was as low as 9½c. History does repeat. Domestic production of copper in 1947 will be 800,000 tons against demand of 1,200,000 tons, meaning that 400,000 tons must come from imports and supply on hand. The government still has 200,000 tons in its stockpile. Substitutions of other metals and materials in place of copper are stupendous. Copper's price must come down.

Good Future for Low Alloy Steels

The triple alloy steels, including the "National Emergency" steels developed during the war, containing nickel, chromium and molybdenum, represent in tonnages sold the largest of any single class of engineering alloy steels in peace time so far. This recalls controversies during the war as to whether the NE steels would pass out of the picture. The 8600 steels are particularly strong in the picture. The past year has seen appreciable expansion also in low alloy high strength steels, such as used in railroad car construction. Hence, these low alloy and cheaper steels promise to forge ahead from tonnage standpoint faster than the higher alloy steels, particularly in the growing competition which follows, and struggle to keep costs down.

AN EDITORIAL

Simple Simon Met a Pieman

Once upon a time there was a pieman named Getmore in fact there was a whole family of Getmores up to their necks in the pie business but not making a great deal of dough at that. They were (somewhat in the order of their original importance):

Eynever Getmore, who put up the money and bossed the enterprise;

Seymour Getmore, a woebegone character who selected and purchased the flour, baking powder, shortening, gelatine, artificial flavoring, powdered eggs, discarded Manhattan cocktail cherries, scrap leather and the other mysterious materials that make up the modern pie;

Igotta Getmore, a baker who was also a skilled worker as you would imagine after inspecting the foregoing bill of materials and who was therefore an active member of Local 606 of the P. R. U. B. (the Professional Racketeers' Union for Bakers) which spelled frontward or backward still means trouble;

Willie Getmore, pie purveyor extraordinary, who peddled the pies to a little guy named Simon and wondered if Marie Antoinette didn't have the right idea after all.

Originally the Getmore pies sold for one buck apiece, out of which each of the working brothers were paid 10 cents each, while 50 cents went to buy materials and equipment. This left a profit of 20 cents; of this 5 cents went to Uncle Sam (who traditionally takes a slice of every pie), while Eynever Getmore the proud capitalistic brother kept 10 cents. The nickel that was left was put in an old flour tin for safekeeping against some future need.

Then one day Uncle Sam, whom the boys had more or less ignored in the past, walked in and said simultaneously that (1) he would now have to have 10 cents out of each pie instead of 5 and (2) brother Igotta Getmore of the P. R. U. B. must henceforth be paid 15 cents instead of 10. Thereupon Eynever Getmore who was always quicker at this sort of thing and therefore fraternally mistrusted observed that this left for him and the flour tin only 5 cents and he right away raised the price of Getmore pies to $1.10.

But within a year the price of flour and the gypsum or whatever they are now using in place of sugar rose 20% and Igotta received a cost of living increase and before he could stop himself Eynever was putting up a sign that said the price of Getmore pies was now $1.20. This sort of thing was repeated a couple of times with flour getting scarcer and Igotta getting fatter until one day Eynever, Willie and Seymour (that's our boy) all of whom come to work every day sit down and cry together about a situation where they are selling fewer and fewer pies at $1.50 each, and where they have very little left for themselves after taking care of the flour company, and the beachcombers who now supply the sugar, and Igotta, and Uncle Sam. Eynever especially takes a dim view of the whole thing because his cut on the enterprise is still only 10 cents per pie and this is plainly a lower percentage than before and also he collects fewer of them and finally it's a thinner dime than the ones he gathered in the old days. As for the ancient flour tin that is now considered old fashioned and languishes empty and neglected on the shelf.

And then like a bad dream who should confront them but the little guy named Simon who buys all their pies only he doesn't buy so many any more and this time he shocks them by requesting the merchandise on the cuff, since he is out of funds, lacks the wherewithal, can't drum up a sou, etc. Readers may remember the classic exchange: Said the pieman unto Simon "Show me first your penny." Answered Simon to the pieman: "Indeed, I haven't any!"

The story might end right here with Getmore Pies, Inc. selling out to Uncle Sam who already has a greater stake in the enterprise than its principal stockholder, but it doesn't. Actually Seymour Getmore who is the materials man in the place finds a way to save on the flour he uses, brings Simon out to where Igotta is fishing for a whale and convinces his brother that there's more to the pie business than dough, everybody including Uncle Sam settles for a smaller cut, the price of pies goes down to a point where Simon can afford to buy them again and lo! in a few years things are back to normal and there's real sugar in pies.

Indeed, our whole industrial economy would be sweeter if something like the foregoing Mother Goose were applied to it in the right places.

FRED P. PETERS

EDITORIAL COMMENT

The Relative Position of Phenolics and Other Plastics

The plastics industry as we know it today began with discovery of the polymerization of phenol and formaldehyde to form the insoluble, infusible material. Such earlier plastics as celluloid, dating back to the 1860's, had been largely confined to novelties, toiletware, and the like, but the new phenolic was useful industrially in electrical and mechanical applications.

At the present time there are several hundred types of plastics, and they are important in both producer and consumer goods. While some of these new plastics are produced from thermosetting resins similar to the original phenolic plastic, many more of the newcomers are of the thermoplastic type. Because of their temperature properties, they are more easily molded than the infusible phenolics. Many of them also offer a wide range of color possibilities, important in present-day consumer goods. They suffer in strength and in temperature resistance, and these disadvantages, while not of great consequence in the novelty trade, sharply limit their use as industrial materials of construction.

The other important consideration for all materials, but especially for industrial materials, in which the phenolics have an edge, is price. Except for certain plastic materials confined almost exclusively to use as electrical insulators, the phenolics are the lowest-cost plastics available today.

If the proportion of the phenolics to the total quantity of plastics in use has declined, the change has not brought a loss in amount of phenolics produced. There has been a steady rise in annual production, and present demand exceeds supply by a considerable margin. The Plastics Materials Manufacturers' Assn. estimates production for the current year at 151,000,000 lb., and credits the first six months of 1946 with a 27% increase over the last six months of the preceding year. Estimates for next year indicate an increase of about 80% over the 1945 production.

The change in relative percentages of phenolics and other types has been due to the increase in number of types of plastics available, and particularly to the increase in types of thermoplastics. Several of these new thermoplastics, especially the vinyls, have shown tremendous expansion during the past few years. Most of these new resins are not direct competitors of the phenolics. However, the greatest activity has been in the field of films and coatings, in which the phenolics have no market.

The phenolics, as has been indicated, are predominantly structural materials, and there is little prospect of their being replaced in this field by any of the present synthetics. They have suffered some loss in molded items, where the lower cost of injection molding can offset slightly higher material cost.

Price, always an important consideration, shows a decided advantage for the phenolics. General purpose phenolics cost about 15 to 20¢ a lb.; the cellulosics may be placed in the 20 to 40¢ range; the vinyls cost about 40 to 60¢. The nylons, polyamides, may be placed in the $1.00 to $1.50 price class. The newer, more dramatic resins are even higher priced, with the allyl esters offered as Kriston selling for about $5 per lb., and the polyfluoroethylene plastic, Teflon, at $15.

The phenolics, then, have a definite field in which they possess advantages over all present competitors—the field of structural applications. They are the first materials to be considered for such purposes as gears, bearings, machine tool uses such as jigs and dies, many types of aircraft structures, building panels, furniture, and electrical uses of many sorts. Their best prospects for the future would seem to lie in this same field, unless new uses not yet apparent should open for them, or a new material not yet known should be found to replace them.

—K. R.

"Packaging"

In the early days of automobile manufacturing, when the customer bought a car he really purchased the mere skeleton. If he was at all affluent, he immediately acquired a windshield, spare tire, set of tools and accessories ad infinitum.

A few years passed and radio came into being. After the "catswhisker" stage was passed and the multi-tube radio was born, even the amateur "handy man" began building his own receivers, having considerable choice as to parts chosen for the assembly.

Again, when home-built sets became passé, one had to assemble a considerable list of accessories, consisting perhaps of loud speaker, lead-plate battery, B batteries, C batteries, battery charger, etc. There was considerable field for the connoisseur to choose accessories with a nicety and exact discrimination.

By that time the automobile maker had "packaged" his automobile and the home radio receiver maker packaged his, particularly after the dynamic loud speaker had been invented. Of course, in those days the word "packaging" had hardly been invented.

But by now the word "packaging" is fairly running rampant and bids fair to get completely out of hand. We have "packaged kitchens," "packaged radio programs" (as we learned from "The Hucksters"). In fact, from the cradle to the grave one can buy "packaged" layouts. The young mother can buy a packaged layette for her babe and grandma can be buried by the "packaged" plan.

We have recently heard of "packaged" industrial plants for shipment abroad, in knock-down form which can be immediately set up at the site with either union or non-union labor.

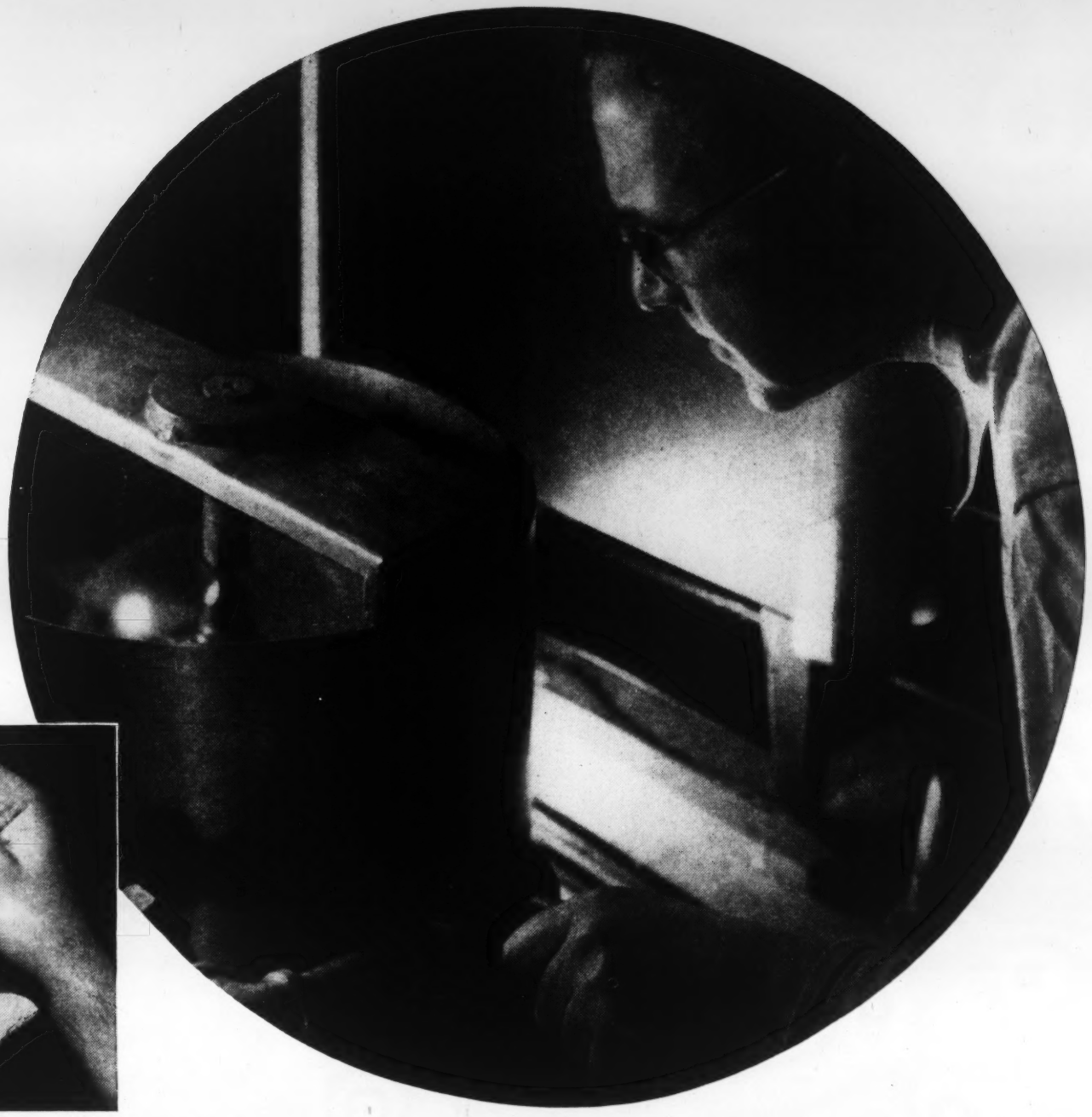
We have wondered how "MATERIALS & METHODS" fits into the picture. Then it dawned on us, with an expansive smile, that we are "packaged know-how" for the metalworking industries. Splendid!

So what?

Does the packaged idea take away all originality and need for thought, concentration and ability to make intelligent choice on the part of us citizens and industrialists? Yes, in a sense, but let it be that way. Well-posted people have made up the industrial packages (we hope), and have already made the studies and choices of materials and assemblies.

So we'll have time to use our brain power on deeper and even more important things.

—H. A. K.



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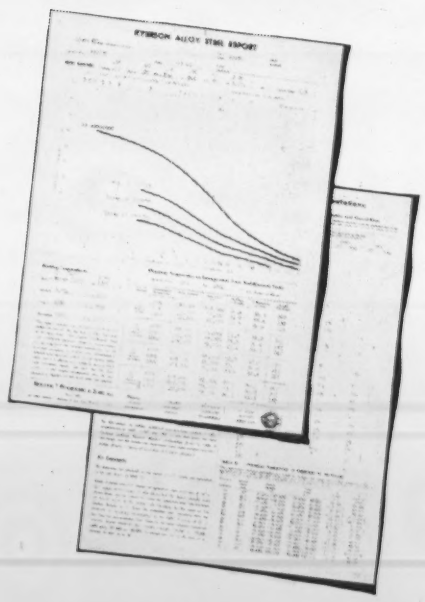

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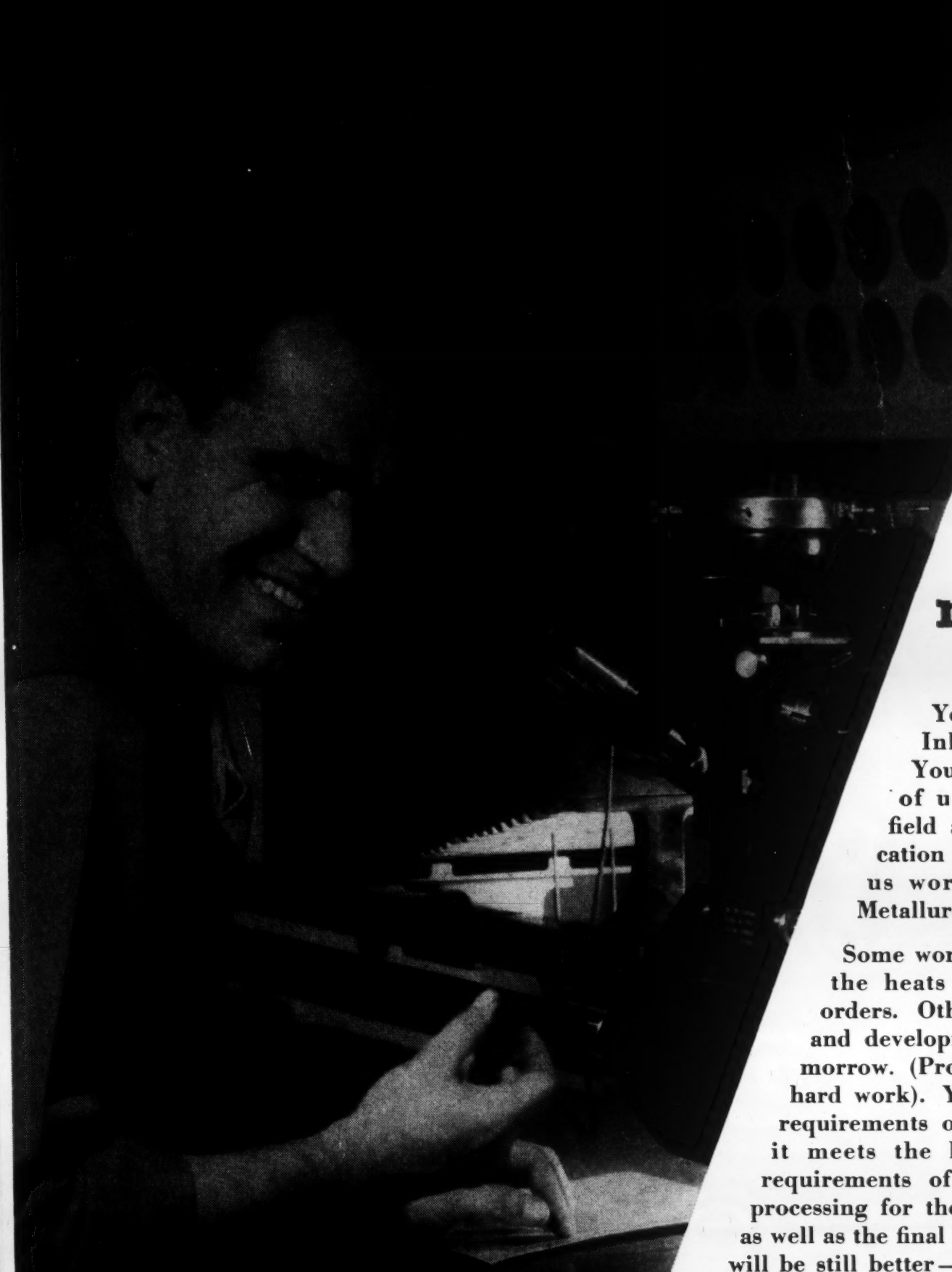

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Materials & Methods

THE METALWORKING INDUSTRIES' ENGINEERING MAGAZINE

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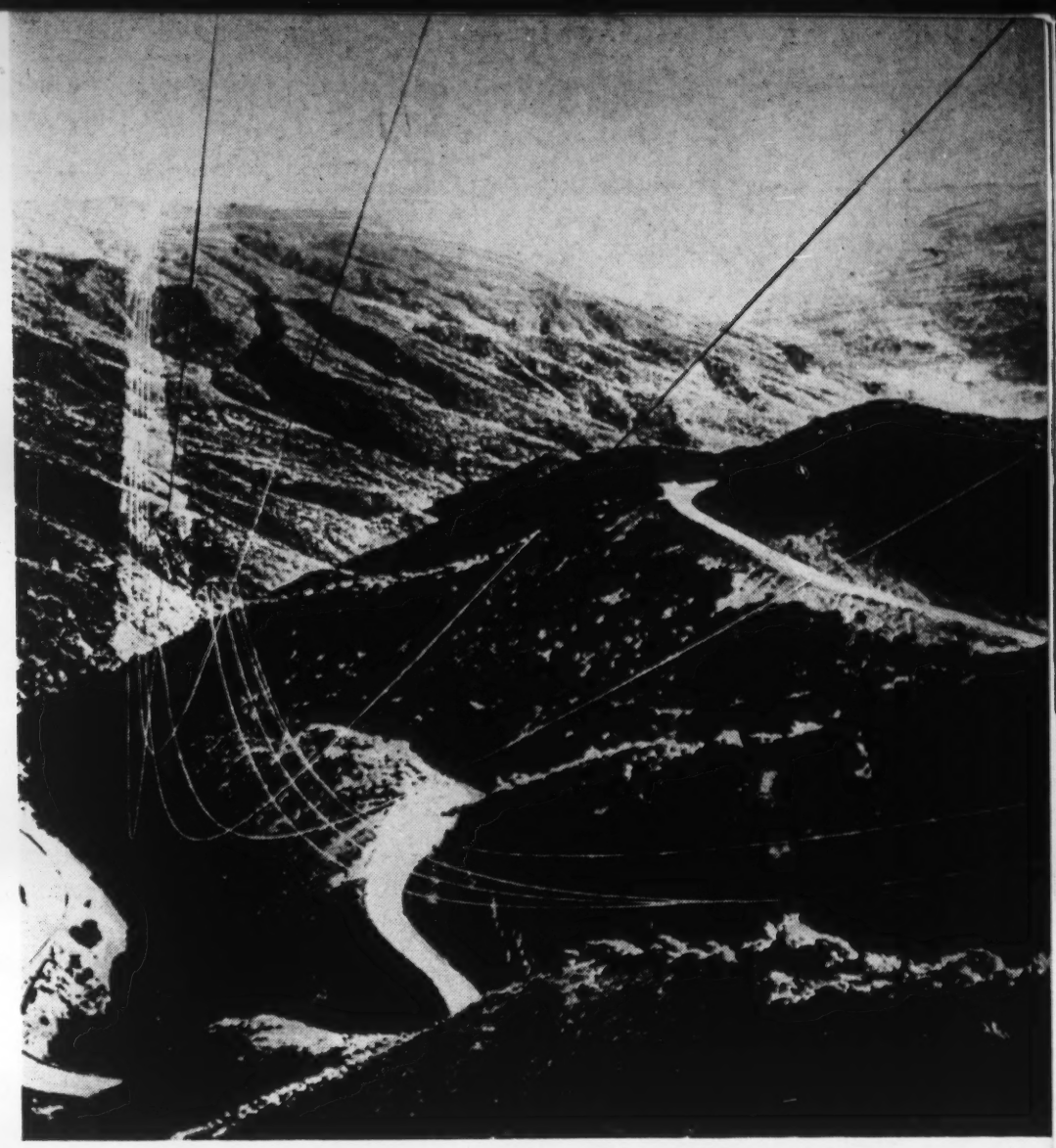


Since aluminum has been used in electrical transmission lines, it has been possible to place poles farther apart, thus helping in another material crisis.

Aluminum versus Copper

by **HAROLD A. KNIGHT,** *News Editor,* MATERIALS & METHODS

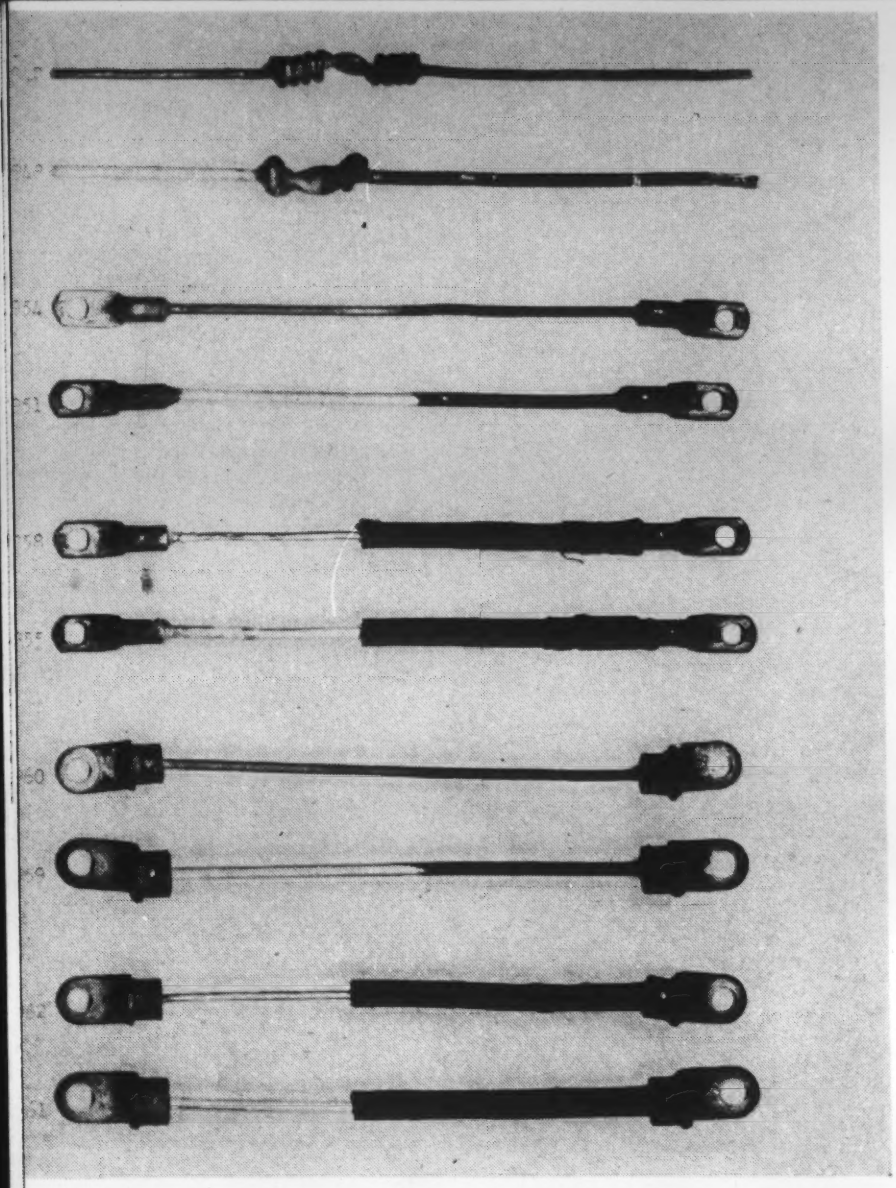
IN THIS ERA OF READJUSTMENTS some of the old established materials are having considerable of a fight to retain their prewar markets. This situation is due in part to the scarcities of some materials, but even more of a factor is the better understanding we now have of the newer materials. Adding further power to the fight for attention of the newer metals is their relative availability. Wartime expansion in facilities for producing aluminum and magnesium has left the country with plenty of these materials and has made them available at prices that are often favorable on a pound-to-pound basis and surely favorable on a volume basis.

This, the second article in a series on the economics of engineering materials, shows how aluminum is now a strong contender for many electrical applications.

One of the most obvious competitions now apparent is that between copper and aluminum. While most of this competition is in those applications taking advantage of the high electrical conductivity of aluminum, other shifts are quite likely.

Domestic production of copper during 1947 is expected to fall some 400,000 lb. short of requirements. The supply situation plus the recent price differentials give aluminum a substantial edge in those cases where it can be used. At the close of 1946 aluminum was priced at 15¢ per lb. for ingots as compared to 19½¢ for copper. Aluminum in some forms is slightly higher.

In selecting materials, whenever the peculiar combination of physical properties is imperative, then price is not a determining factor. However, where sufficient flexibility exists to permit the use of a wide range of physicals, then price becomes the determining factor. Besides such applications, there is a field where physicals play a minor part such as stainless steel on top of the Chrysler building or copper alloys



In comparing copper and aluminum wires with various joints it was found that the two types of conductors are highly comparable.

for store fronts. Thus considered, the markets for basic metals can be said to fall into three categories: the basic market, the price market, and finally, the luxury market.

These markets sometimes overlap and in other cases are misapplied. The longer a material is in use, the more shaken down are its markets. This is true of copper and its alloys. Many believe that markets in copper alloys which may be taken by such materials as aluminum, magnesium and plastics will be more than offset by the quantity of copper alloys required for the expanding production of these newer materials. That this thinking is logical is borne out by the constant growth experienced in all basic material markets.

Before the most recent war it was an axiom that when copper ingot metal sold at 14¢ and aluminum at 20¢, the relative use of the two metals in long-span power lines was 50-50, according to the Edison Electric Institute. Six months or more ago, when the prices were about ½¢ per lb. apart, there was a strong movement to use aluminum instead of copper. At that time the cost of copper cable was 25% greater than aluminum cable of equal conductivity per unit length.

Helping to promote substitution of aluminum for power lines is an accentuated scarcity of poles. The pole shortage has resulted in longer spans which now range up to between 475 and 600 ft. The light weight of steel reinforced aluminum cable makes the longer spans practicable.

Some of those who have recently changed from copper to aluminum will not commit themselves as to permanency of the new uses, preferring to speak of the change as a temporary emergency measure.

Even before aluminum became cheaper than copper it was stated that the cost per linear foot of condenser tubes for heat exchangers, in the ¾-in. O.D., 0.040-in. wall thickness size, is definitely less for aluminum alloys 2S and 3S than for ordinary seamless steel tubing. (This would indicate that the aluminum tubing was then cheaper than tubing of copper or copper alloys.)

When the price of aluminum dipped below that of copper it assured aluminum's invasion of the electrical field for any voltage and current application. Copper lost the high voltage transmission field long ago; recently copper surrendered the medium high voltage field. Now the last remaining electrical field, that of wire, braided and insulated conductors, where copper was thought to be supreme, is being taken over by aluminum.

Because of the price situation two prominent suppliers of wire—one of solid building wire and the other of weatherproof wire—have turned to aluminum. Likewise, a copper company now produces aluminum tubing for certain purposes and intimates that these applications may never return to copper.

All power generated at the new Jennison station of the New York State Electric & Gas Corp. is transmitted by aluminum buses. These include all outdoor 46-kv. and 13.8-kv. buses and indoor 13.8-kv. isolated-phase leads between the generator, transformers and main switchgear. Most fasteners and fixtures are also of aluminum. In this particular case, aluminum was more readily available than copper and its use was favored by the WPB.

The engineering firm responsible for building the Jennison station did not make any close comparative cost study between materials, but indicates that, certainly under today's conditions aluminum would be cheaper.

As an emergency measure during the war electric motors were wound with aluminum in place of copper. When using frames designed for copper, the horsepower ratings of aluminum motors was lower, since conductivity of aluminum is only 84% that of copper. For one war application 15,000 aluminum-wound motors were ordered. Sometimes the natural oxide coating of the aluminum is allowed to serve in place of conventional insulation.

Aluminum Building Wire

When the United States Rubber Co. recently started making aluminum building wire it was not a wild experiment. France has installed millions of feet of aluminum building wire since 1940. French sources report today that the technique of using aluminum building wires is well developed. Electrical installations with aluminum wire may be undertaken with complete safety.

Moreover, the old bugaboo against seacoast installation has no terrors for U. S. Rubber who point out that on Fishers' Island in Long Island Sound there is

Here submerged aluminum cable is given a resistance test before shipment from a U. S. Rubber Co. plant.

still in operation a 5-mile span of aluminum cable installed in 1899. It is just as good as the day it was put up according to the manager of the island's light and power company.

It is well to scrutinize U. S. Rubber's building wire more closely. During the war new types of aluminum alloys were developed, one of these resulting in "EC aluminum" ("E", electrical; "C", conductor). This is the best electrical conductor in the aluminum family and when made into wire is referred to as "hard drawn aluminum," equivalent in many physical properties to "soft drawn copper." Breaking strengths and stiffness are about the same for both wires.

U. S. Rubber advocates for average building wire circuits the use of the same ducts or conduits for aluminum as for copper wires. Thus, the same conduits that carried copper wire can carry aluminum, using too the same number of wires. The larger diameter of the aluminum wire is offset by a smaller insulation, attainable by the Laytex dip process which puts on a very thin coating in contrast to former cumbersome insulation layers. Consequently, an insulated aluminum wire in size 12 AWG has an overall diameter less than the 14 AWG copper Type R building wire.

Sizes 6 and larger of aluminum building wire are supplied with heat resistant insulation. Since the National Electric Code permits aluminum conductors to carry 84% of the current rating allowed copper wire, it is evident that aluminum conductors with the heat resistant insulation will carry the same current as permitted for Type R building wires.

Some new fluxes developed during the war can be used, along with solder, equally well on copper and aluminum. They are noncorrosive and penetrate the aluminum oxide on the surface (a process that used to give trouble). At demonstrations before house electricians, the workmen handled aluminum soldering like experts after one or two trials. As far as coupling devices, adapters, etc. are concerned, we can use with aluminum the same devices used for copper. In making soldered joints, techniques are the same for the two metals, such as dip ladle, torch and solder rod, and soldering iron. The aluminum wire can be produced on the same machinery used for drawing copper.

Recently the Aluminum Solder Corp. has received exclusive manufacturing rights on this Continent for a new aluminum solder, called "Prolyt," from the Handex AG of Zurich, Switzerland. With it sheet aluminum, electrical wiring, etc. can be soldered "with great simplicity" and with less danger of corrosive agents weakening or marring the joints, without the use of fluxes or other special agents.

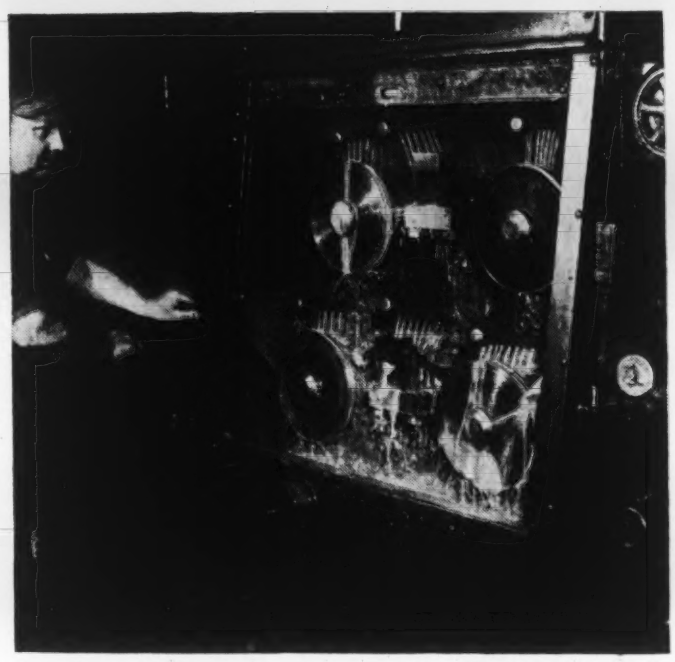
Aluminum sponsors, of course, have to overcome the traditional fondness for copper as a nice material to work with. However, the extensive experience in handling aluminum during the war at aircraft plants, etc. schooled thousands of artisans in the newer material.

Much experience was gained with aluminum electrical wiring during the war. Such wire saved weight. Thus, the aluminum wire in the new B-36 saves 250 lb. in weight. In aircraft work it was observed that the flexibility and tensile strength of aluminum building wire is similar to that of copper. Stretch and elongation resulting from pulling into conduit is much less than copper and can be limited to 1 or 2%.

Another advantage is for vertical risers where stress on aluminum is half that for copper risers. An aluminum riser can be safely self-supporting for twice the vertical height of riser.

A comparative cost of principal kinds of power

Here aluminum is braided into electrical cable on equipment almost identical with that used for other materials.



Aluminum wire being formed in an intermediate wire drawing machine where the metal passes through 14 reduction steps. (Courtesy: U. S. Rubber Co.)

cable was compiled in 1946 by Page W. Choate, senior engineer, Carolina Power & Light Co., the unit for comparison being 10 lb. Thus, copper cost at that time $1.60; steel, 55¢; ACSR (6 or 7 strands of aluminum to 1 strand of steel), $1.91; copper weld, $1.88. Thus, though the aluminum cable was more expensive per lb., the fact that it will go at least twice as far as copper makes it cheaper. The real cost would be, therefore, around 95¢ as against $1.60 for copper. At today's prices aluminum would fare even better.

For window screening aluminum can compete from standpoint of raw material and processing. Comparative costs per square foot some time ago were: iron, 5¢; aluminum, 8¢; and copper, 14¢. Copper wire can, of course, be drawn down from No. 8 gage to No. 40 gage with no intervening anneal. Aluminum must undergo one anneal, but still it is cheaper.

Considerations as to the Future

So much for the immediate situation. But what about public acceptance of aluminum as a substitute, what are its limitations and how will the far distant future shape up? There is always a resistance of inertia in accepting a new material. Andrew Carnegie believed that steel was inferior to wrought iron as a structural material and fought steel as long as he could. It's lucky for humanity that steel won, even though a hundred Carnegies could not hold off development of a superior and cheap material.

It is easy to imagine copper rising to the class of a precious metal, much as is silver today, which is used industrially, in art and coinage. For compact electrical conductivity there is no superior. Thus, for underground cables in cities where compactness of electrical conductivity is necessary, it has no peer. It may well be that for bulk items aluminum will be used, with copper in the smaller and more precise mechanisms and gadgets. It may be a sort of go-between metal—between steel and silver as to preciousness and delicacy of use.

After all, copper comes from ores that are 1 to 3% metallic as against 35 to 55% for aluminum. Under such accident of nature copper cannot expect to be a mass material. However, the future of copper supply is not altogether black. According to official figures there is a 25-year supply of U. S. copper of present grades. New methods of exploration have uncovered additional reserves, such as in Arizona under desert wash. The higher the selling price, the more incentive to explore.

Aluminum is one-twelfth of the earth's surface. It is assumed that from 700 million to 1,200 billion tons of bauxite is distributed throughout the world, one-third of this of proved high grade ore, enough to last 50 years at war peak consumption. There is enough competition among aluminum producers to make for a comparatively stable price. Authorities predict that the power cost for producing aluminum—and that is one of the main costs—will get down to ½¢ per lb. and conceivably 1/5¢, since plant maintenance and labor are small factors. The drop in the selling price has been severe—from $54 per lb. to 15¢ today. Can it not go down further?—At least as to ratio with other materials, through their rising?

Automobile makers have testified that they will not use aluminum on a large scale unless the price dips to 10¢, but it could easily achieve a relative price of that figure by the sharp advance in other materials.

Some go so far as to predict that just as steel has been a leading business barometer for a few generations, so will the light metals be one in the near future. It is claimed, too, that due to the lower melting points of the light metals they are easier and cheaper to handle all the way from raw state to finished product than copper and steel. Light metals take less expensive equipment, too.

Again, more and more useful things can be made of aluminum scrap because of better methods of segregation and better and cheaper processes for purifying it. The old fallacy that any alloy produced from scrap is thereby inferior has been exploded by the American Society for Testing Materials, whose subcommittee on light metals said: "The terms virgin, primary and secondary metal should not be used in connection with aluminum and magnesium alloys, either in ingot form, as castings, or as wrought products. The quality and physical properties of these alloys or products made from them are dependent on the composition of the final products and the quality of workmanship in manufacturing." All aluminum alloys are produced of varying blends of scrap and new metal, regardless of producer.

In conclusion, let us quote from Dr. Colin G. Fink, who spoke exclusively for this article: "The elimination of copper in the electrical industries appears impossible today—but an announcement to that effect tomorrow is not improbable. However, it is much easier to picture plumbing without 'plumbum' and galvanizing without zinc."

Costly furnace shut-downs for week ends are not necessary with development of this method for holding charges in gas carburizing furnaces up to 72 hours.

Suspended Carburization

by S. L. WIDRIG, and JOHN E. REED, *Spicer Manufacturing Div., Dana Corp.*

and O. E. CULLEN, *Surface Combustion Corp.*

TO HOLD THE CHARGE in a carburizing furnace indefinitely without damage or ultimate change in the material has long been the aim of metallurgists and those responsible for production heat-treating operations. To do this in a continuous gas carburizer is even more significant. Yet today it is being accomplished on a regular production basis with one or more furnaces and has been in use for nearly a year.

The economic advantages accruing from the ability to do this are obvious. Formerly, the time lost in re-starting production after a week-end shutdown ranged up to 24 hr. This loss of production time and furnace capacity is now eliminated. Material is immediately available for further processing. No previous stock piling to form a backlog of parts while awaiting furnace output following the shutdown is necessary. The process becomes again truly "continuous," the furnace keeping pace with production both before and after production ceases for the weekend. There is no "lag" at either end of the shutdown period.

To successfully suspend the carburizing action, yet hold the material in the furnace without damage for as long as 72 hr., involves numerous factors, all of which have now been determined.

It may be noted at the outset that since the problem is a combination of furnace design and then of manipulation, there is no "royal road" to quick, easy attainment of the desired result in any furnace of the continuous type. However, the procedure used in accomplishing the result in furnaces of the Spicer Manufacturing Div., Dana Corp. at Toledo, can well be applied with necessary alterations in techniques as demanded by conditions existing within the heating zones of other continuous type furnaces. It is with such alterations and modifications in design that the Surface Combustion Corp. cooperated with Spicer in developing the method to a successful conclusion.

Accomplishment of suspended carburization was attained first by considering:

(1) Time—Temperature—Carburizing Medium, the inevitable "Triumvirate" of all carburizing, and

(2) The timing of the necessary manipulations.

Since case depth and carbon gradient are functions of time, it was reasoned that as the temperature was dropped to such a point that absorption and diffusion of carbon approached nil, and the carburizing medium was of such a nature as to be practically neutral, time would no longer be a factor in the process. But the accomplishment of these conditions in a furnace was by no means easy, especially in a furnace of the continuous type. In a continuous furnace, the charge ranges in condition from green work just inside the charge door to finished, reheated work at the discharge end. The problem of manipulation therefore is paramount. It is largely by studying the effects of changes in operation of the furnace, involving alterations in the atmosphere, temperature changes in various furnace zones, timing within zones and similar factors that the key to success was ultimately found. Some minor alterations in furnace design were found necessary. The work involved more than a year of test and experiment and is here disclosed for the first time.

The furnaces in which suspended carburization is applied were originally designed to carburize and to slow-cool only. This design had been subsequently altered so that the first two zones are used for carburizing (about two-thirds of the furnace length), the third for cooling, and the fourth for reheating.

These changes in furnace design had included the construction of two low arches, one at each end of the cooling zone, to facilitate the removal of heat in the cooling zone without affecting the other zones. Another alteration from the original design had been to move the carburizing gas inlet ports farther toward the charge end of the furnaces to avoid undue sooting of the work in the cooling zone. An auxiliary blower also had been installed to accelerate the cooling rate in the third zone. The only change directly due to the "suspended carburization" process was the installation of gas inlet ports on the end walls of the discharge ends of the furnaces. These ports are used only during application of this process. It may be noted

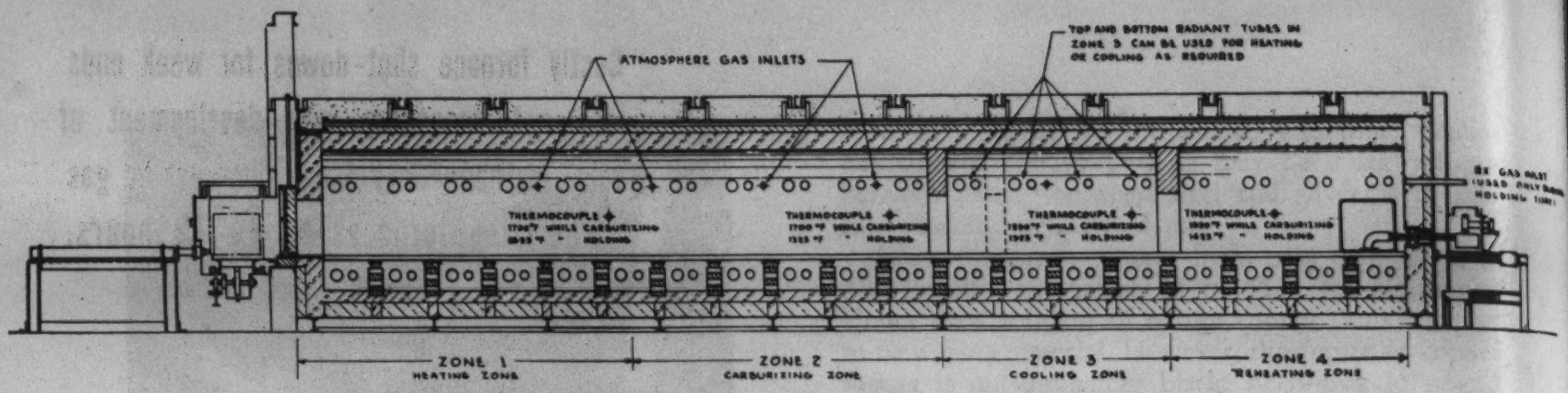

TOP AND BOTTOM RADIANT TUBES IN ZONE 3 CAN BE USED FOR HEATING OR COOLING AS REQUIRED
ATMOSPHERE GAS INLETS
THERMOCOUPLE
THERMOCOUPLE
THERMOCOUPLE
THERMOCOUPLE
ZONE 1 HEATING ZONE
ZONE 2 CARBURIZING ZONE
ZONE 3 COOLING ZONE
ZONE 4 REHEATING ZONE

Fig. 1—Continuous gas carburizing furnace adapted to suspended carburization.

also that these furnaces are of the three-row pusher type, and contain three rows of trays. The original furnace design and changes made are shown in Fig. 1.

Relative to manipulation problems, it may be noted that temperature changes can readily be confined to restricted areas of the furnaces, while a change in the carburizing medium will affect the entire length of the furnace.

Temperature Changes

The timing of all temperature changes occurring in the first two zones was found to be extremely important. They must be made while maintaining correct case and carbon gradient on the hold-over work, while at the same time they must be correlated with the carbon potential of the furnace atmosphere so as to eliminate precipitation of soot. Furthermore, even though sooting is avoided, if the carbon potential should be too high during the cooling period, excessive carbides will be built up in the case. This is particularly deleterious to work lying in the third zone.

As a result of a long series of tests, it was established and is now regular practice to make the optimum time for reducing the temperature in the first two zones approximately 2 hr. before the end of the production cycle. At this time 15 empty trays, *i.e.*, three rows of five trays are in the cool zones of the furnace and final work of the production run is all in the fourth or reheat zone. Work to be held over within the furnace is located in the first two zones, plus approximately two hours production of green work still to be moved into the furnace. The work already in the furnace has moved into position at normal heat but in an atmosphere gradually depleted as to carbon potential. Green work will enter the furnace under a decreasing temperature and a further depleted atmosphere. This is desirable, since the work will be brought back to carburizing temperature upon resumption of operations, and in this time interval will pick up the carbon that it missed on entering the furnace.

Thus, approximately 2 hr. before the end of the production cycle, the temperature in the first two zones is set at 1550 F. The zones will reach this temperature by the time of the last push of work into and through the furnace.

The temperature changes in the third zone must be so regulated and timed to give the production work leaving the furnace the benefit of an adequate cooling time, yet still bring this zone up to 1550 F at the same time as the first two zones reach this temperature. To accomplish this, the temperature in the third zone is set at 1550 F 2½ hr. before the end of the production run. This time is established by the entry of the empty trays into the third or cooling zone. It was established through knowledge of the position of the work within the furnace and by visual inspection of the production work still in the cool zone at the time of the change.

During the last 2 hr. of production preceding the hold-over period, the first two zones are falling in temperature to 1550 F, and the third zone is rising to this temperature. At the completion of production the entire furnace is thus at 1550 F. This temperature previously existed in the fourth zone since it is normally used as the reheat temperature. At the end of the production cycle the fourth zone contains the empty trays.

When the last tray of normal production work is removed from the furnace, the temperature control for the first three zones is set from 1550 to 1325 F. That of the fourth zone is set at 1450. This allows the entire furnace to fall in temperature simultaneously. By lowering the temperature in the fourth zone, which is full of empty trays, overheating of the third zone is prevented. It is desired to hold this third zone temperature at 1325 F, along with the first two zones. From 4 to 5 hr. are required for the first two zones to reach 1325 F, the first zone falling in temperature faster than the second. This temperature setup is maintained during the hold-over period until time to put the furnace back into operating condition.

It is important that the furnaces not reach carburizing temperatures too long before operation (pushing) is resumed. To do so causes an increase in case depth and a corresponding decrease in carbon gradient, particularly in work in the second zone of the furnace.

The timing necessary to bring the furnaces back to temperature for resumed production is quickly determined from trial. There is, of course, a variation from zone to zone and from furnace to furnace. In preparing the furnaces for production after the period of suspended carburization, all four zones of the furnace are raised to the regular carburizing temperature of 1700 F and then zones three and four are dropped to their normal operating temperatures. This entire operation requires approximately 4 hr. The third zone is cooled to its operating temperature of 1200 F

by use of the auxiliary blower (cooling unit). It is customary to set the fourth zone at 1550 F when the auxiliary blower is turned on. This brings the entire furnace to operating temperature by the time production is to be resumed. (See Chart, Fig. 2.)

Carburizing Atmosphere

The effect of temperature changes on gases of various compositions is so definite that it is essential to control the nature of the gas as closely as possible during the temperature changes. Due to the importance of the gas composition, it is here considered separately from the time cycles previously outlined. This factor influences the timing of adjustments in the gas phases of the furnace; for if the gas composition remains constant during cooling, the carbon potential will rise. The phases, therefore, run the gamut from a rich carburizing gas at the start of the setup, to a non-carburizing, non-sooting gas under actual hold-over conditions, and vice versa as production is resumed.

Under the normal conditions of operation, all RX or carrier gas is poured into a common header. From this header the necessary gas for each of the controlled atmosphere furnaces is drawn. This, incidentally, has been of inestimable worth in permitting the shutdown, cleaning and reconditioning of RX units without interference with the production of any of the furnaces. Four units are used in regular production for six furnaces.

For suspended carburization, however, it is necessary to control each furnace through an individual RX unit rather than the common header. By using an individual gas-producing unit for each furnace, greater flexibility during the period of gas manipulations is obviously obtained. It is likewise apparent that all furnaces will not empty at the same time or change in temperature at the same rate. Since these conditions determine the gas composition in the furnace, separate units must be employed. There is a further advantage in the fact that the furnaces not engaged in a hold-over can continue to operate or be conditioned for operation from the header where regular gas may be maintained while a hold-over is in progress.

Two factors apparently influence the precipitation of soot within the furnace. If the gas used during the period of low temperature is too rich in carbon potential, or if the natural gas is not shut off soon enough in the furnace as the shutdown period is approached, sooting will occur. (Note: Other factors will also cause soot. However, they are dependent on faulty operation or improper maintenance of equipment and need not be discussed here.)

To offset the first of these factors (low temperature and the high carbon potential) the RX units are leaned in the first tests to produce a gas of approximately 1.1% CO_2 with a dew point of 65 to 75 F. The dew point was later lowered to 40 to 50 F with a corresponding CO_2 of 0.4% at the RX unit. Lowering the dew point prevented condensation which was occurring in the RX gas lines especially during cold weather. The effluent gas of the furnaces will run between 1.0% and 1.2% CO_2 using the above gas. The furnace will likewise average about 5 F higher dew point than the influent gas.

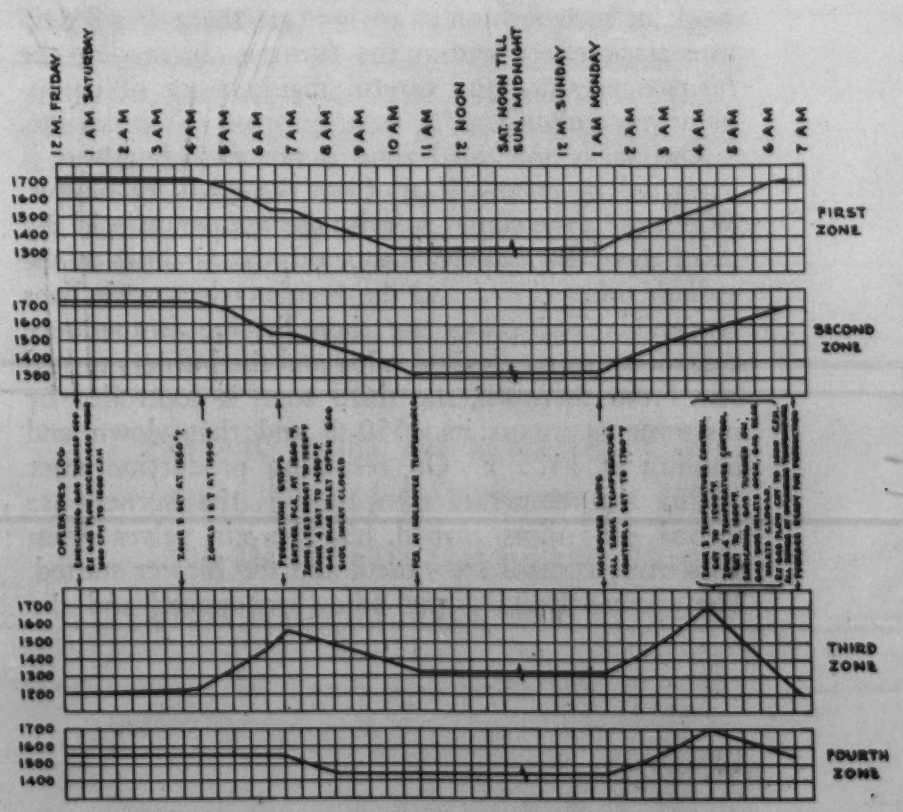
To offset the second factor, it was found necessary to shut off the natural gas supply to the furnace approximately 6 hr. before the end of the production run or, as on an ordinary week-end, around midnight Friday night. This time varies slightly between furnaces, since it affects case concentration also. Another detail requiring consideration is the condition of the furnace. A clean furnace versus one in use after five weeks production will tend to vary slightly in relation to the timing of the gas shut-off. (Furnaces cleaned every six weeks.)

The build-up of massive surface carbides shown in earlier tests disappeared with the raising of the dew points for the holding period and the earlier restriction of the natural gas. It is, of course, directly allied with the same conditions that produce a sooting effect. However, it is still possible to have a gas so lean that no soot is precipitated and still build up surface carbides. This was particularly true of work in the third zone of the furnace where in the tests it was subjected to a raising and lowering of temperatures in a low temperature range. The lower temperature retards diffusion and allows the surface to build up to a relatively high carbon concentration. Slight decarburization occurred in one trial when a high dew point (75 F) was used. A certain amount of water condensed in the gas pipes and in the cooling chamber at the discharge end of the furnace—directly under the inlets. This was eliminated when the dew points were lowered.

Maintaining Quality

Shutting off the natural gas and altering the nature of the furnace atmosphere by temperature changes while production work was leaving the furnace posed several questions. Could carbon concentration be maintained and the proper cooling effect obtained?

It was found necessary to increase the flow of gas into the furnace during the period of temperature changes and the cutting off of the natural gas. In week-day operation, approximately 1000 c.f.h. of RX



TIME - TEMPERATURE CYCLE FOR SUSPENDED CARBURIZATION

gas and 100 c.f.h. of natural gas are used. When the natural gas is shut off, the RX flow is increased to 1300 c.f.h. This compensates for the loss of natural gas and likewise partially compensates for the loss in furnace pressure due to the contraction or, let us say, decreased expansion of the gases within the furnace as the furnace temperature drops. When the furnaces are filled and set for the hold-over, the air-gas ratio of the generating units is slowly adjusted to produce the gas previously mentioned. When the furnaces are returned to temperature for resumed production, the gas generators used for the hold-over are cut out and the furnace is given straight RX gas from the header, by units not involved in the hold-over.

This allows time for properly readjusting and checking the hold-over generators before again coupling them to the common header.

Each furnace has its own little idiosyncrasies. These variations are brought out during a hold-over. One furnace may heat or cool faster than another. A gas-tight furnace is necessary. One may have doors, tubes, etc., requiring maintenance. While a general procedure can be used for all furnaces, slight variations are necessary to compensate for the individuality of each unit.

Regulation of Pressure

During normal operation an effective pressure of 0.2 to 0.3 in. (water column) is maintained within the furnace. During the first trial with suspended carburization, it was found that the pressure had dropped to 0.05 in. during the hold-over. To counteract this, the gas flow was increased to 1300 c.f.h., as noted previously. Since this did not entirely answer the problem, cocks were installed in the bleeders at each end of the furnace. The bleeder at the discharge end (ordinarily venting one-third of the gas) was practically closed. This brought the pressure back to approximately 0.15 in., an adequate differential. If a higher pressure is needed it can be obtained by restricting the vent at the charge end of the furnace. The purpose of furnace pressure is to prevent the influx of air at any leak in the shell or around the various furnace openings. During one or two trial runs with a low furnace pressure, soot formed on the work in such fashion as to indicate there was a definite stack effect within the furnace. Increasing the furnace pressure and careful maintenance of equipment have eliminated a recurrence of this condition.

Ordinarily the third zone is not fired but heat is extracted by means of air from the auxiliary blower. When the time comes to raise the temperature in the third zone, this blower is shut off, the air lines to the radiant tubes closed and the regular eductor air lines reopened. The pilots are then lit, the temperature control set to the desired value and the burners turned on. From there on, the third zone is controlled by instruments up to its 1550 F and then down and holding at 1325 F. On resuming production after raising the temperature to 1700 F, the burners are turned off, pilots turned off, the air valves from third zone control are closed, and the blower started. The blower lines to the tubes are opened and the temperature dropped to 1200 F by the regulators on the auxiliary blower.

It was found that the heat in the fourth zone carried over into the third zone during the hold-over. To avoid this condition, the temperature of the fourth zone was set to 1450 F, as previously noted. This was not drastic enough. The first two burners of the fourth zone were, therefore, turned out, namely, near the region where it abuts the third zone. This was sufficient to prevent overheating the third zone and gave enough heating radiation to hold the fourth zone as long as no work was moving through the furnace.

From the standpoint of safety it is necessary to have some region of the furnace above the ignition point of any air-gas mixture. If desired, the furnace could then be opened without fear of an explosion. Probably the only events that could require opening a furnace would be a gas failure or a plant fire of such proportions that gas and power would have to be shut off.

In setting up the third zone prior to the hold-over, it was essential that no production work be present as the temperature was raised. It was impossible to arrange the timing so as to run hold-over work immediately behind production work and still have sufficient time to manipulate the temperatures. This helps to explain the use of the empty trays.

Conclusion

All large carburizers in the plant are now being held over week-ends loaded with work. The results have been highly satisfactory. In no case have any situations arisen that would call for the rejection of material processed. Within the past few weeks minor difficulties have been eliminated and the process of suspended carburization is now a routine procedure.

The factors which determine whether or not the process can be applied to any continuous furnace are (1) that a combination of atmosphere and temperature be available which will prevent carburizing and diffusion reactions wherever work is present in the furnace, and (2) that a high temperature be maintained in one zone, preferably the final zone of the furnace to avoid explosion hazards. Obviously the latter factor requires that this zone be devoid of work.

While the present furnaces employ a special heating cycle, wherein the work is carburized, cooled to below the critical and reheated to proper quenching temperature, many similar furnaces employ a simpler cycle. In such cases the temperature is held practically constant throughout the furnace. In furnaces of this type the entire furnace with the exception of one zone, as mentioned above, can be lowered and raised in temperature as a unit. Nor need the process be limited to the high carbon concentrations obtained and preferred by Spicer. Furnaces which are constructed to provide control of temperature and composition of atmosphere to obtain any desired range of case characteristics can be utilized. Thus, any furnace which can meet these requirements, either initially or by modification of design, can be used for the process of suspended carburization, regardless of the specific temperature cycle involved.

Blended plastics are used in these products which include an ice bucket, de-icer ring, shoe sole, gasoline hose and screw driver. (Photos: Courtesy B. F. Goodrich Chemical Co.

Blended Plastics Provide Wide Range of Characteristics

by **KENNETH ROSE,** *Engineering Editor,* MATERIALS & METHODS

AT A MEETING of the Society of the Plastics Industry several years ago the then president, George Scribner, predicted the development of "plastic alloys," in which several plastics would be intimately combined, by fusing or otherwise, to offer a new series of plastics of blended properties. The importance of such alloying is clear—if a plastic must withstand somewhat higher temperatures than its normal range in a given application, the addition of a higher-temperature plastic might produce a composite that would meet requirements. This would be a long step toward producing "tailor-made" plastics for each application.

Unfortunately, alloying of plastics is usually rather difficult. Many of the compositions that could contribute valuable properties are incompatible with the types with which they should be alloyed. Even when compatible, the physical mixing is usually a difficult matter.

A family of materials recently produced and now being announced might be called such plastic alloys. It consists of a blend of synthetic rubber with the standard phenolics, in proportions ranging from about 8% to about 90% of synthetic rubber, balance phenolic. Properties range all the way from a solid resin of considerably increased toughness to metal-to-metal adhesives of the Cycleweld type.

The mixtures might also be called "plasticized" or "tempered" resins. The rubber industry prefers to call them "blends." The nomenclature is not especially important—but the fact that blended plastics have been produced with the indicated range of properties is. The compositions having about 12% of synthetic rubber added might be thought of as plasticized, or tempered, phenolics, but even this amount is in excess of the amounts of other plasticizers used in ordinary practice.

Synthetic rubbers of a particular chemical group are used for these new compound plastics. Chemical resistance is a desirable property for this purpose, as otherwise parts made from the new material would take on some of the defects of the rubbery constituent.

Phenolic resins and synthetic rubbers can be blended in such varying ratios that all characteristics of both of these material types can be utilized.

Polyvinyl chloride plastic and acrylonitrile rubber are combined to produce the highly polished sheets shown. The other sheets use the same rubber base plus phenolic resins.

Rapid deterioration when in contact with oil or greases is a characteristic of natural rubber, so that the choice tends toward the oil-resistant grades of synthetics. These are of three general types:

(1) Chloroprene type; offered under the trade name Neoprene
(2) Disulfide type; includes the various formulations of Thiokols
(3) Nitrile types; acrylonitrile and butadiene copolymers.

Of these three types, the last-named has been shown to be readily compatible with many other compounds, and has been especially useful as a solid plasticizer or tempering agent in certain of the vinyls and phenolics. The nitrile-type synthetic rubbers must be thoroughly freed of all impurities to be easily compatible, however, so that not all grades are suitable for this purpose.

The nitrile synthetics now commercially available are offered under four trade names:

(1) Hycar, a product of B. F. Goodrich Chemical Co.
(2) Perbunan, made by Standard Oil Co.
(3) Chemigum, prepared by Goodyear Rubber Co.
(4) Butaprene, produced by Firestone Rubber Co.

Most of the work to date, both experimental and commercial, has been done with certain grades of Hycar. The phenolic used is generally a phenol-formaldehyde resin, and those offered as general purpose molding materials by Durez Plastic & Chemical Co., Bakelite Corp., Wilmington Chemical Co. and Monsanto Chemical Co. have given satisfactory results in tests made thus far.

It should be emphasized that most of the work done to date has been of a preliminary nature, and that even laboratory results are not yet comprehensive enough to warrant drawing conclusions as to physical properties except in a general way. Data given here are derived from laboratory test batches. While physical properties have not yet been determined accurately enough with various mixes and under a sufficient variety of conditions to permit stating definite maximum values, the blended materials have been used industrially for a sufficient length of time to bring recognition of their worth.

The first widely publicized use of phenolic-rubber mixtures was in the metal-to-metal adhesives, developed gradually over the past ten years. These were of many types, and each provided several different formulations for different conditions of use or method of application. All embodied the idea of a phenolic resin incorporated in a natural or synthetic rubber, and cured to an infusible film as bonding was effected. They approximated "50-50" compositions of rubber and resin. While natural rubber was the rubbery constituent in the earliest types, later compositions used various synthetic rubbers. The use of Cycleweld adhesive, developed at Chrysler Corp., was one of the important wartime achievements.

The more recent developments in the use of these blended materials date back only two or three years. In spite of their newness, they have already achieved industrial use over the entire range, from phenolics with a small percentage of synthetic rubber added, to synthetic rubber containing a small percentage of phenolic resin. Properties vary from the hardness, brittleness, and infusibility associated with the pure phenolic resins, to the softness, flexibility, and extensibility of the synthetic rubber. The wide range between these limits is well covered.

Blends Fall Into Two Groups

The entire range of blends can be conveniently grouped into those compositions containing 40% or more phenolic, in which the admixture of synthetic rubber serves to temper the brittleness of the resin, and those of 60% or more synthetic rubber content. In the former group the material is rigid, and is usually formed by molding in much the same manner as ordinary thermosetting resins. Addition of the rubber serves to:

(1) Decrease brittleness. Impact values are increased considerably.
(2) Improve water resistance, with consequently greater dimensional stability.
(3) Improve chemical resistance.

In the latter group, containing 60% or more of synthetic rubber, the material is a modified elastomer, and is frequently used as an unsupported sheet. Addition of the resin to the synthetic rubber gives the following properties:

(1) Compression set increases.
(2) Tensile strength is increased.
(3) Elongation decreases rapidly.
(4) Tear strength and abrasion resistance increase.
(5) Hardness increases.

The resin-synthetic rubber blend in this range can produce an unsupported sheet with properties similar to those of similar plasticized polyvinyl chloride unsupported sheets, and at a quite substantial saving. Whereas the vinyl sheet will cost slightly more than 40 cents a lb., the blend can be made at a cost of about 20 cents per lb. As the resin content increases beyond 35% the possibility of carrying considerable loading, and of producing hard vulcanizates, brings the material into the molding field.

A general picture of the change of properties with

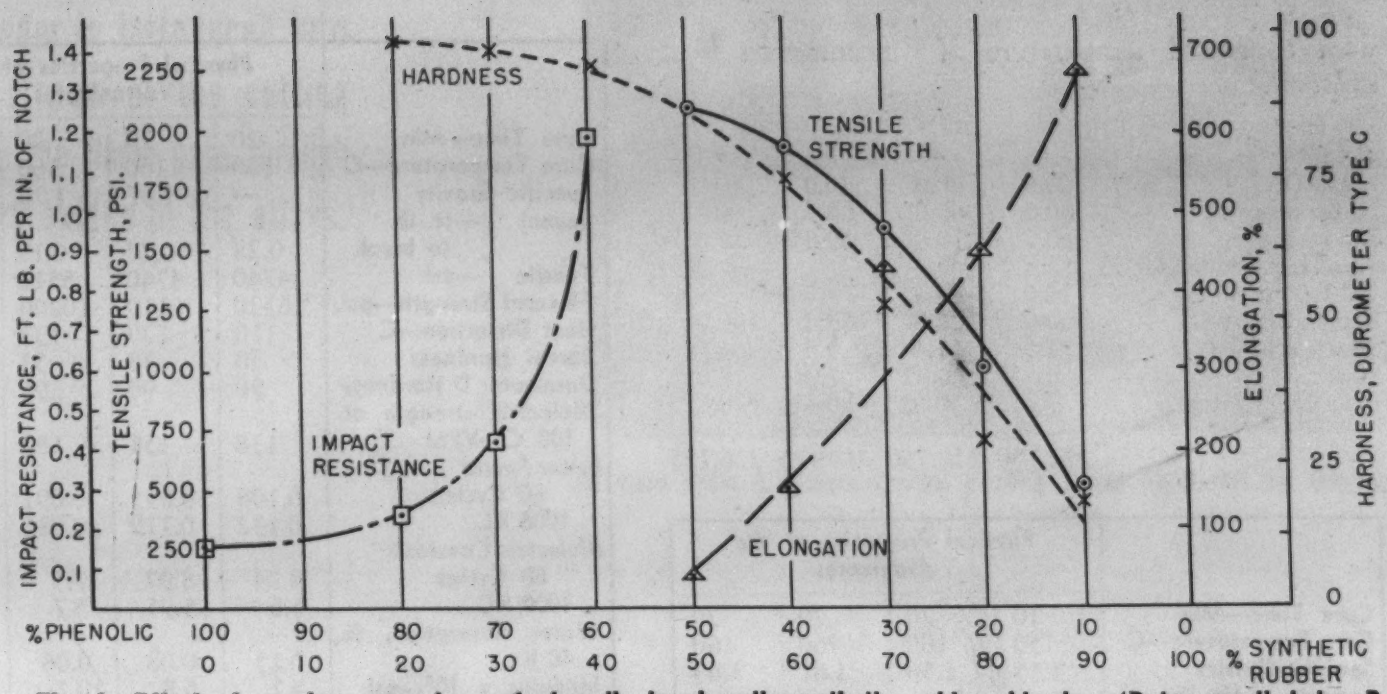


Fig. 1—Effect of varying percentage of phenolic in phenolic-synthetic rubber blends. (Data supplied by B. F. Goodrich Chemical Co.

change of composition can be obtained from the curves in Fig. 1. These curves were produced from laboratory data upon test batches of the indicated compositions, and are intended to show the trend of properties rather than typical values for the various compositions.

The molded phenolics with synthetic rubber added have been tested during the war in aircraft parts, for which the addition of 8 to 12% synthetic rubber gave a much-desired increase in impact resistance. With the end of the war, blends containing about this percentage of synthetic rubber have been used for kitchen utensils, sink strainers, trays, etc. An automobile steering wheel containing 8% nitrile rubber has been reported. A material with 8 to 12% synthetic rubber has been produced as a substitute for hard vulcanized rubber, and has been found to possess considerable flexibility.

In addition to the higher resistance to impact shown by the blends over hard rubber, there is an increase in resistance to distortion at elevated temperatures. Hard rubber softens at about 170 F. While definite values have not yet been fixed for the softening point of the blends used as substitutes, a definitely higher temperature can be endured.

As the nitrile rubber content increases the blend becomes a tough, hornlike material that has been used for mallet heads, screwdriver handles, ice buckets, and similar articles. The content of rubber may be in the range of 40 to 50% for these. Steam valve disks have been made of this "50-50" mixture when the service temperature was not excessive.

In the second range of compositions, comprising those with 60% or more of the nitrile synthetic and serving primarily as elastomers, those with 70 to 75% rubber content are most widely used at present. Produced as a flexible sheet, they are sometimes embossed to produce attractive and durable artificial leathers. Experimental products have been made up such as book bindings, upholstery, pocketbooks, and like applications. The sheet may be calendered and press-polished to resemble patent leather, and in this form is very applicable for women's purses, women's shoes and similar articles. A wide range of colors is possible.

Addition of more phenolic produces a stronger, more abrasion resistant sheet, used for severe service. This material has been used for shoe soles, basketball covers, football covers, and similar purposes.

Most of these sheets tend to become stiff at low temperatures. Addition of "loading" reduces this tendency, and the blends are able to carry a substantial amount of such loading. With increase of phenolic content above 35% this loading may be as much as four times the rubber content. Clay, whiting, softeners, or carbon black may be added to produce the vulcanizable material already referred to. Five to 10 min. at 310 F is adequate for curing of such formulations.

When the resin content exceeds 80%, mill mixing becomes a difficult operation. For lesser concentrations of phenolic, mill mixing of the constituents is the rule, and presents no serious problem. The temperature during mixing should be held at a point below the melting point of the phenolic if optimum physical properties of the blend are to be realized. This temperature limitation is not important when the concentration of phenolic falls below about 35%.

Blend Characteristics

Detailed results of some of the tests made in the laboratories of B. F. Goodrich Chemical Co. show the properties obtained with formulations as outlined. In the first set of four tests a blend of 60 parts resin and 40 parts synthetic rubber have been vulcanized with various amounts of sulfur, and at several different curetimes and temperatures. The percent ages of resin and rubber are varied in the second set of tests,

with time and temperature of vulcanization held constant.

Test No.	*1*	*2*	*3*	*4*
Hycar OR-25	40.0	40.0	40.0	40.0
Durez Resin 12687	60.0	60.0	60.0	60.0
Zinc oxide	10.0	10.0	10.0	10.0
Coumarone-indene-resin (M P 20 to 30 C)	10.0	——	——	——
Suprex Clay	100.0	100.0	100.0	100.0
Stearic acid	1.5	1.5	1.5	1.5
Sulfur	0.625	0.625	7.0	14.0
Benzothiazyl disulfide	0.525	0.625	0.625	0.625
	222.750	212.750	219.125	226.125

	Physical Properties of the Vulvanizates			
Cure Time—Min.	10	20	20	20
Cure Temperature—C	150	160	160	160
Specific Gravity	1.55	1.56	1.61	1.63
Impact —ft.-lb. to break	—	0.27	0.15	0.15
Tensile —psi.	5780	5100	5280	3870
Flexural Strength—psi.	9180	7600	8080	6950
Heat Distortion—C	120	132	121	108
Barcol Hardness	25	36	48	55
Durometer D Hardness	—	90	95	95
Dielectric Strength at 100 C—VPM	218	193	243	199
Power Factor				
60 Cycles	0.031	0.053	0.077	0.075
1000 KC	0.07	0.12	0.065	0.061
Dielectric Constant				
60 Cycles	7.6	8.38	7.78	6.87
1000 KC	4.9	5.7	4.85	4.25
Water Absorption, %, 48 hr.	0.09	0.11	0.06	0.06
Modulus x 10^3 psi.	—	4.4	5.5	10.7
Schenectady Arc sec.	182	186	184	164
Shrinkage mil./in.	5.4	8.4	11.5	11.1

Test No.	*5*	*6*	*7*	*8*
Hycar OR-25	40.0	40.0	25.0	15.0
Durez Resin 12687	60.0	60.0	25.0	15.0
1206-HCR-12 Masterbatch	——	——	50.0	30.0
Durez Resin 12687	——	——	50.0	70.0
Suprex Clay	100.0	150.0	150.0	150.0
Stearic acid	1.5	1.5	1.5	1.5
	201.5	251.5	251.5	251.5

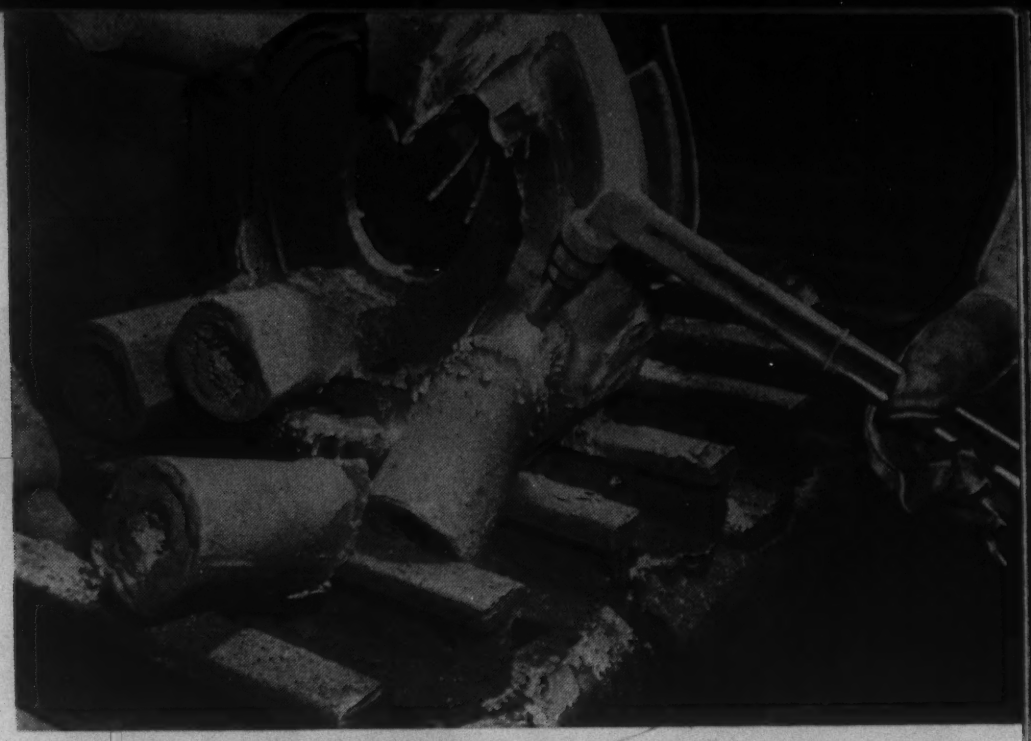
	Physical Properties of the Vulvanizates			
Cure Time—Min.	20	20	20	20
Cure Temperature—C	160	160	160	160
Specific Gravity	—	1.67	1.70	1.72
Impact —ft.-lb. to break	0.28	0.27	0.17	0.17
Tensile —psi.	4740	4740	5510	5210
Flexural Strength—psi.	6320	6110	10200	8770
Heat Distortion—C	110	120	133	142
Barcol Hardness	30	38	53	60
Durometer D Hardness	90	90	95	95
Dielectric strength at 100 C—VPM	138	151	182	179
Power Factor				
60 Cycles	0.108	0.095	0.091	0.085
1000 KC	0.132	0.119	0.081	0.062
Dielectric Constant				
60 Cycles	8.74	8.97	7.5	7.46
1000 KC	5.6	5.95	5.7	5.3
Water Absorption, %, 48 hr.	0.15	0.08	0.06	0.08
Modulus x 10^3—psi.	4.2	5.8	10.7	12.2
Schenectady Arc—sec.	184	156	185	187
Shrinkage mil./in.	7.8	7.8	6.8	5.0

The results achieved by these alloys, both in the laboratory and in industry, serve as an auspicious introduction to this method of producing new plastic materials. Even with the incompatibility of many types limiting the field, possibilities are wide. News that at least one alloy containing three plastic constituents has been used commercially serves to point up these possibilities. A material consisting of a blend of a phenolic, a vinyl resin, and a nitrile rubber is being molded to the handles of electrician's tools to provide a good grip and electrical insulation, and users report excellent bonding to the steel as well as good mechanical and electrical properties.

Research and development work with the blended plastics is going forward in the laboratories of several companies, and six months from now a more comprehensive report upon possible formulations, and upon cure conditions for obtaining best physical properties may be expected. In the meantime, the attention of the materials engineer has been called to a new group of plastics, with interesting properties and wide industrial possibilities.

These parts are made of Buna N and phenolic resins and are much like hard rubber in appearance. (Courtesy: Durez Plastics & Chemicals, Inc.)

Iron-rich powder is introduced into the oxygen stream of the cutting torch to make the flame pass through the refractory oxides in the alloys.



A riser from a stainless steel casting being hand cut by the powder cutting process.

Powder Cutting of High Alloys

by D. H. FLEMING, Jr., *Development Engineer, The Linde Air Products Co.*

OXYGEN CUTTING OF STAINLESS and other high alloy steels, as well as nonferrous metals and, to a lesser degree, cast iron, has been a problem in fabrication for many years. With the development of a powder cutting process, oxyacetylene cutting now has been extended to include most oxidation-resistant materials.

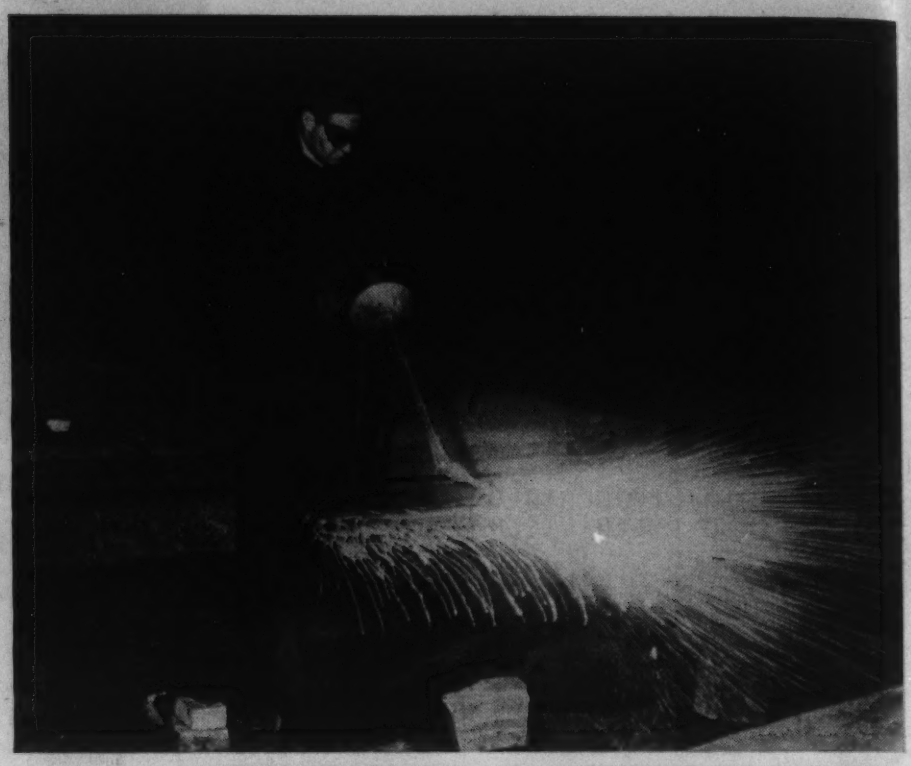
Success of oxyacetylene cutting of ferrous metals is due to a rapid chemical reaction between iron and oxygen. This is easily accomplished in ordinary carbon steels because iron oxide melts at a lower temperature than does the base metal. However, in cutting steels that contain alloying elements, such as chromium and nickel, and in cutting of many nonferrous metals, oxides that melt at a higher temperature than the base metal are formed. In other cases, formation of oxide is not highly exothermic and does not support the reaction. Such refractory oxides prevent a continuous reaction because they protect the base metal from further oxidation until the base metal melts. For example, in stainless steels chromium, which has a high affinity for oxygen at elevated temperatures, forms highly refractory chromium oxide on the kerf's face and prevents further oxidation.

In cutting, four methods have been commonly used in the past to overcome the refractory effect of oxides. In one method, the material to be cut is heavily preheated and oversized cutting nozzles are used; the hand-cutting blowpipe is manipulated with a reciprocating motion. A second method is to hand-feed an iron rod or wire into the reaction zone. The rod provides molten droplets of iron oxide to act as a fluxing agent in the cutting. A third method is to use a plain carbon waster plate on top of the material to be cut; this plate provides products of oxidation which give the necessary heating and fluxing action in the cutting operation. The fourth method is the use of a carbon or metallic electrode which creates a temperture high enough to melt away the stainless steel. All of these methods are slow and, because the cutting is rather ragged, they are suitable only for the roughest work.

The powder cutting and scarfing process overcomes difficulties encountered in the older methods of oxygen cutting oxidation-resistant metals. Powder-cutting is accomplished by using a finely divided iron-rich powder together with cutting oxygen to provide sufficient support to oxidation of the material being cut. Powder is heated to ignition temperature by the oxyacetylene preheat flame. The powder is ejected into the oxygen stream and burns, creating a high temperature reaction. Refractory oxides that are formed are continuously removed by a combination melting and fluxing action. The powder is non-hygroscopic, which makes for ease in dispensing, and it is also non-irritating and non-toxic.

Essential apparatus necessary for powder cutting includes a powder dispenser and a powder blowpipe. The powder dispenser holds the powder; it has an ejector unit from which the powder is picked up by

Machine powder cutting of a riser from a centrifugal stainless steel casting.



Stainless steel ingots can be powder-scarfed to remove surface cracks and tears and spongy metal.

a compressed-air stream and delivered to the blowpipe through ordinary rubber hose. Basically, the hand blowpipe is the same as a regular oxyacetylene blowpipe, but in addition, has powder passages as an integral part of the construction.

In addition, a series of four machine cutting attachments have been designed to be added to ordinary machine cutting blowpipes and the usual cutting nozzles so that standard oxyacetylene equipment can be adapted to powder cutting by the addition of a powder cutting attachment and a powder dispenser.

Cutting Stainless Steel

All types of stainless steel can be oxygen-cut by the powder cutting process. There is no definite upper limit on thicknesses of metal to be cut. Twenty-six inches, which is the heaviest section encountered to date, has been successfully cut. Stack-cutting is desirable for single plate thicknesses under ¼ in. because of the improvement in cut quality which results. In stack-cutting, tight clamping of the plates is not necessary, because the high heat reaction jumps over any ordinary gaps between plates.

Cutting speeds on stainless steels are approximately equal to, or greater than, those possible on carbon steel. For example, on 1-in. stainless steel plate, cutting speed is 14 to 16 in. per min. as compared to 14 to 19 in. per min. on plain carbon steel; on ½-in. stainless, speeds of 20 to 24 in. per min. are achieved, compared to 17 to 24 in. per min. for carbon steel; on 4-in. stock, 7 to 8 in. per min. as compared with 6.5 to 9 in. per min. for carbon steel; on 20-in. stock, 2 to 3 in. per min. compared with 1.5 to 3 in. per min. for carbon steel. Hand-scarfing operations on stainless steel are carried out at a speed approximately one-fourth to one-third the speed used on carbon steel, with equivalent oxygen flows and the added factor of powder.

A feature of the process which makes for shorter total cutting time is that flying starts are possible in both cutting and scarfing of cold steel. The high heat of combustion created by iron powder in the cutting-oxygen stream completely eliminates preheating time common to carbon-steel cutting, and particularly to older methods of cutting stainless steels.

Quality of resulting cut surfaces when using powder cutting approaches that obtained in regular oxyacetylene carbon steel cutting. The surface of powder cut edges is rougher, possibly because of selective oxidation of the various alloy components in the cut material. With powder cutting, a nozzle one size larger than generally required for regular oxyacetylene cutting of the same thickness is necessary. Thus, the amount of metal lost through the powder cutting process is somewhat greater. However, this slight additional metal loss is not generally considered significant.

There are no unexpected or unusual effects of powder cutting on the metallurgical qualities of the material. If stainless steel is of the hardenable variety, that is, of the martensitic group of the 400 series, hardening of the cut surface will result, and the same procedures that are followed on oxyacetylene cutting low-alloy steel plate to prevent its cracking must be followed. As far as corrosion resistance on unstabilized material is concerned, a small amount of carbide precipitation has been noted at a depth of ⅛ to ¼ in. from the cut surface; that is in the region where the temperature gradient is between 1,000 and 1,500 F, the critical temperature range for this material. There is a thin fused layer on the actual cut surface,

0.005 to 0.007 in. in depth on ½-in. plate, and a light grinding pass should be made across the surface. Powder-cut areas on unstabilized materials from which scale and fused metal have been removed will satisfactorily withstand any service in which as-welded steel gives satisfactory performance. Tests on different types of stainless steels have shown that the heat effect produced by powder-cutting and subsequent welding on the powder-cut bevel are the same as the heat effect produced by welding on a machined bevel. Columbium or titanium stabilized materials are not affected by powder-cutting any more than they are by welding. Powder-cut or scarfed surfaces which are to be subsequently rolled or forged require no special treatment inasmuch as the subsequent heating operations will put the material in its original condition.

Powder cutting is applicable to contour or shape cutting operations in the same manner as is ordinary oxyacetylene cutting. It can also be used to bevel edges for welding. Such uses of the process in metal fabricating are expected to permit use of shapes and designs not before possible because of limitations of mechanical cutting methods.

It is difficult specifically to discuss the matter of costs of powder cutting, because of many relevant factors which vary according to application. However, a few general cost characteristics can be discussed. In general, powder cutting operations are about twice the cost of equivalent carbon steel cutting with the powder accounting for 25 to 50% of the total cost. Based on several specific cases, powder cutting of stainless steels is approximately one-half that of cutting by oscillation.

Powder Cutting Applications

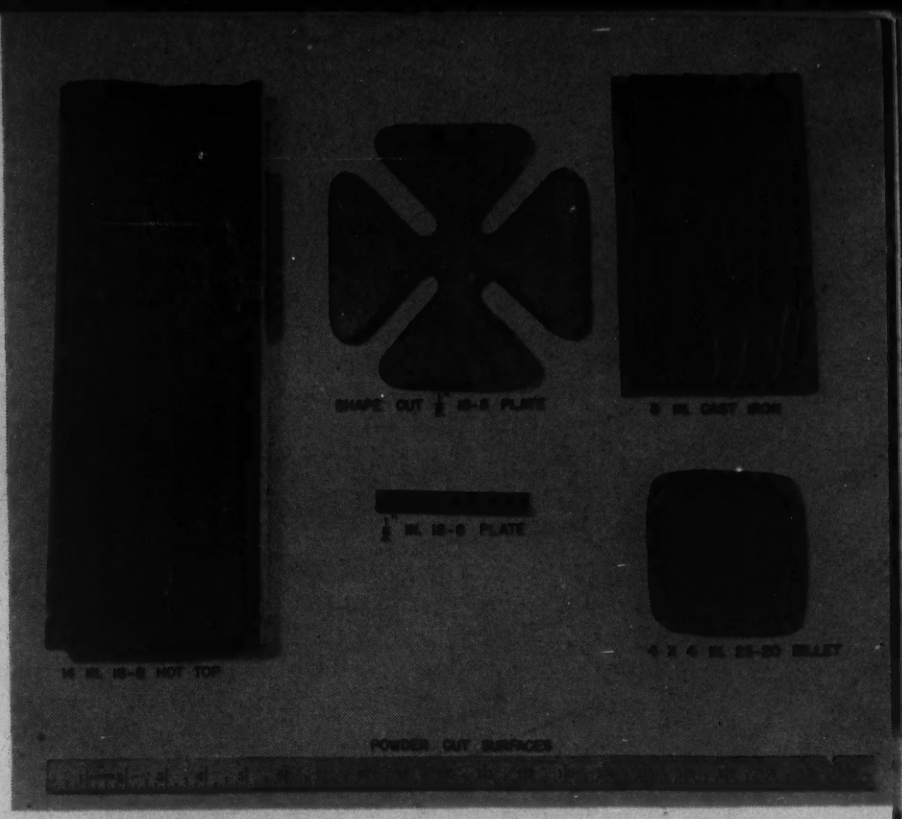
Powder cutting and scarfing have applications in the manufacture of stainless steel from ingot to the final finished product. In the steel mill, the process is used in conditioning stainless steel and in cutting sections generally ranging from 3 to 26 in.

Bloomed ingots are generally covered with severe cracks and corner tears, in some cases 2 or 3 in. deep. To remove these defects by grinding is laborious; by powder-scarfing, the job is considerably shortened. A 12,000-lb. ingot can be conditioned in 4 to 6 hr., as compared to around 48 hr. required for grinding.

Small unrolled ingots often have a spongy surface approximately 3/16-in. deep, which can be removed easily by powder scarfing. Heavy slabs and billets frequently have the same spongy condition, but, in addition, are so badly cracked that grinding would be uneconomical. The speed of powder scarfing now makes it feasible to reclaim material in this condition.

On slabs and smaller cross-sectioned billets (3 to 4-in. thick) the depth of defects is not great, so grinding and scarfing are approximately equal on a cost basis, but two to three times as much tonnage can be conditioned by one scarfing operation in a given time.

Powder cutting can be used in steel mills to cut off hot tops from large ingots or bloomed ingots. It



Characteristic cut surfaces in various materials over a wide range of thicknesses.

is possible to remove the hot top from ingots 18-in. thick and 56-in. wide in 28 min. Another use of powder cutting in the steel mill is for removing cracked edges of slabs before re-rolling. In many cases the cracked condition would ordinarily cause the slab to be scrapped. Speed obtained by using the powder proces is three to four times that of the carbon arc method. The slabs are also cut into smaller sections for further rolling.

Medium-sized billets can also be cut to short lengths. The billets are laid out on a bed, and the cutting proceeds from one billet to the next without stopping. With a set-up of this type, 115 stainless 18:8 billets, 3½-in. square, can be cut in half in approximately 1 hr.

In the stainless steel foundry, the process has found considerable application in the removal of risers that heretofore had been melted off by carbon or metallic arcs. In removal of risers, the cutting speed is nearly equivalent to that for carbon-steel risers, but consumption of oxygen is somewhat higher. The process has particular advantage over the carbon arc method for cutting risers with large cross-sections. A 6-in. dia. riser can be removed by powder cutting in a matter of 1½ min. overall time, whereas the

The cut on the left was made by the old oscillation method; the one on the right was made with powder cutting. The powder cutting was 3½ times faster.

same riser removed by carbon arc would require about 25 to 30 min. cutting time.

With a careful operator it is possible to cut closer to the casting than is possible by carbon arc cutting, and furthermore, there is no carbon pickup on the pad surface. This means that the pad remaining on the casting will not contain hard spots and will be considerably easier to grind down to the casting contour. The use of powder permits the cut to penetrate to a metal body, even though it is coated with a layer of refractory material. In the foundry this consists of sand which frequently adheres in corners of the work. Thus, with powder cutting, a rigid cleaning technique prior to riser removal is not necessary. This characteristic of the powder cutting process may be useful in ordinary carbon-steel foundries for removal of risers prior to sandblasting, thereby increasing effective sandblasting capacity by eliminating extra tonnage of risers that were previously attached to castings while they were being cleaned.

The powder-cutting process has extended the many uses of oxyacetylene cutting to the metal fabricating and forming field. As was mentioned previously, the process can be used for shape-cutting stainless steel as well as for beveling plate edges. In addition, powder cutting can be used in welderies for grooving out weld defects. At present, a nozzle larger than that used on carbon welds must be used, so the groove cannot be made as narrow or as deep as when grooving out carbon steel welds. Development work on grooving stainless steel welds is still in progress.

Powder Cutting Other Materials

Although powder cutting was primarily developed for use on stainless steel, it is also applicable to the cutting of cast iron, high alloy steels, and certain nonferrous materials.

Cast iron is not considered an oxidation-resistant material, but to cut it with standard oxyacetylene equipment, a special oscillation technique is required, because of the presence of graphite flakes. Using the powder cutting process, cast iron from thin sections up to 26 in. thick has been cut as effectively as stainless steel with definite indications that 26 in. is by no means the maximum. For any given thickness, the oxygen and powder-flow requirements are roughly equivalent to those for stainless steel. The cutting speed, however, is reduced approximately 50%. For example, on 8-in. cast iron the cutting speed is 2 to 3 in. per min. as compared with 4 to 5 in. per min. on stainless. The quality of cast iron cut surfaces as compared to stainless steel is equivalent with occasional ripples on the cut surface. Powder cutting gives a smoother surface than that resulting from the oscillation technique. Effect of powder cutting on metallurgical qualities of cast iron depends upon the combined carbon content. Resulting hardness and heat affected area are roughly comparable to steels having a carbon content equivalent to the combined carbon content of the cast iron. In addition, a layer 0.005 to 0.010 in. thick of fused metal, which has the characteristics of white iron, is produced on the cut surface.

In stack cutting, tight clamping of the plates is not necessary. These 12 10-gage, type 304 stainless steel sheets were held together by only two C-clamps and a piece of steel slab.

The cost of powder cutting cast iron, because of its slower cutting speed, runs roughly 100% more than for stainless steel cutting. The process has been used extensively in a large cast iron ingot-mold foundry for removal of lumps that result from mold failure. In some cases lump removal requires an 18-in. deep cut. Other applications include removal of risers from cast iron rolls and the removal of solidified cast iron from blast furnace ladles and hot metal cars.

The powder cutting process can be used on ferrous alloys having higher alloy content than the stainless steel types. Alloys which have been successfully processed include the Hastelloy nickel-base alloys and high strength high temperature materials such as N-155 or Timken alloy.

A number of nonferrous materials are being successfully powder cut, and development work is progressing on others. Nickel-base alloys, such as Monel and Inconel, as well as pure nickel itself, have been cut to a maximum thickness of 5 in. With these materials the extremely high-temperature reaction between the powder and the oxygen stream cuts the metal primarily by melting rather than by oxidation. Cutting speed is 20 to 30% of that for stainless steel; the cut surface quality is somewhat inferior to that obtained on stainless steel. Among the applications of powder cutting to nickel-base alloys is shaping of plate for fabrication, particularly cutting special shapes of Monel. In one case, elliptical Monel fins are being shape-cut for a special type boiler. The plate is ½-in. thick and is cut at a speed of 5½ in. per min. The cut surface is almost as good as obtained on stainless steel, with very little dressing-up required.

With methods such as the powder cutting process now available for rapid and economical cutting of alloy steels and nonferrous metals, more advantageous use should be made of these materials. Also, development work on the powder cutting process is continuing; as a result, the future may see further refinements and the introduction of many new powder cutting applications.

Panels are sent through the infra-red tunnel in a double line.

Electrostatic Spraying of Steel Wall Panels

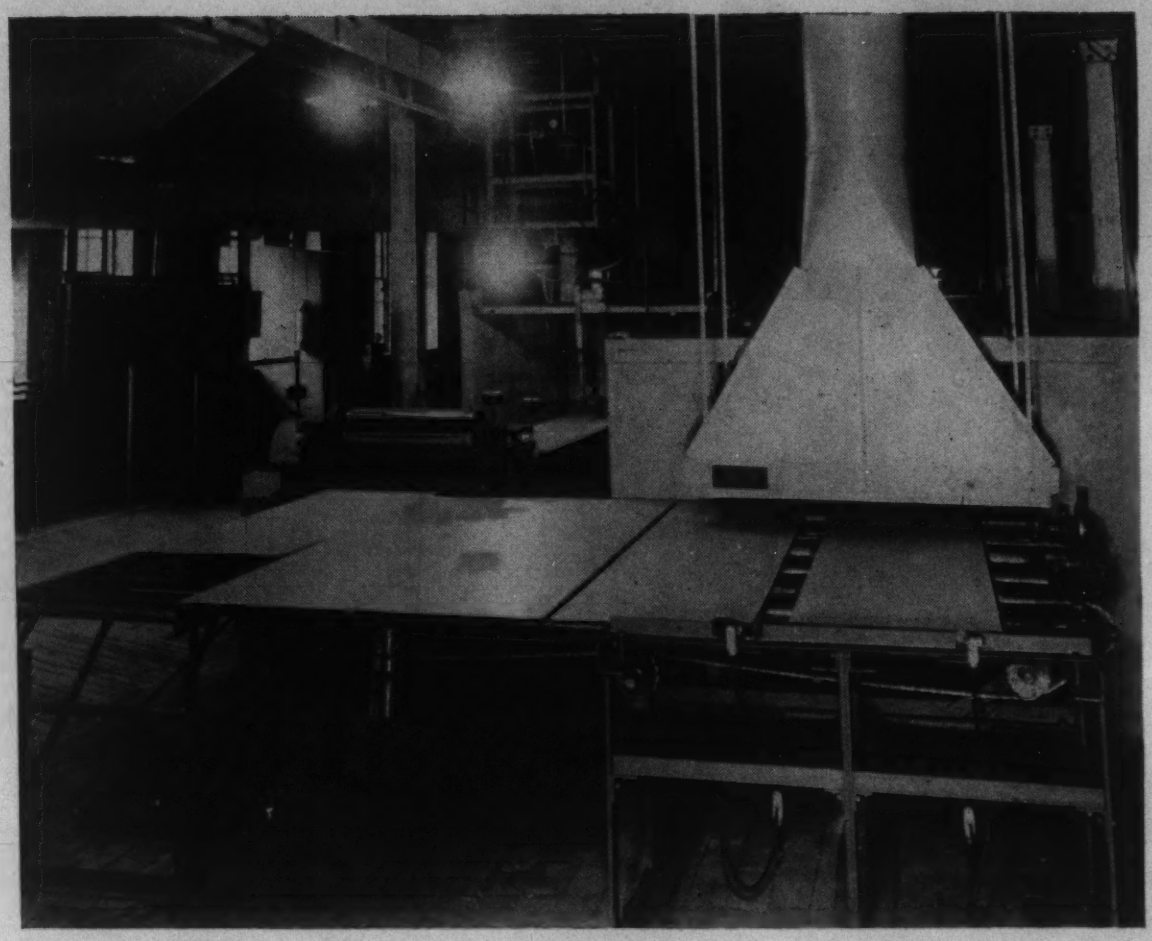
by W. S. REED, *Plant Engineer, Martin-Parry Corp.*

This modern line for the production of steel wall panels saves on the application of finish coats through the use of electrostatic spraying and infra-red drying.

THE MASS PRODUCTION of steel partitions and steel wall panelling has been an important part of the manufacturing business of Martin-Parry Corp. These panels are made in standard sizes, 24-in. wide and 93-in. high, and are designed so as to snap into place on steel studding, with wood grained or enamelled finishes available in a variety of colors. As they are much used for offices, stores, theatres, banks, and other commercial buildings, finish of the panels is required to be both durable and decorative, and the production of this finish is carefully controlled.

Finishing of the panels is done in two automatic systems, the first including the bonderizing of the sheets and applying of the prime coat, while the second provides for the surfacing of the assembled panel. As originally set up, the prime coat was applied in a dip bath, and the surface coats were sprayed on, with gas-fired ovens doing the drying in both systems.

A serious fire destroyed the No. 2 system June 19, 1946. Limited production was resumed about two weeks later with improvised equipment, and with manual spraying of the panels. It was decided to take



After panels pass through the infra-red tunnel they are cooled by an air blast.

advantage of the necessity for replacement by modernizing the system, using infrared drying to replace the gas ovens and electrostatic spraying to secure greater economy in applying the finish coats. Basic equipment for these processes was secured, and the production line was set up with whatever material could be obtained. Conveyors were of the chain belt type, and supports were made from angle iron, pipe, and I-sections. Spray booths and infrared tunnels were made from rejected sections of the panelling being produced. About five weeks after the fire automatic production was resumed, and so well has the emergency equipment functioned that it has not been found necessary to replace it.

The panel consists of a facing sheet, of one gage of steel, rolled so as to have a slight crown; a stiffener sheet, corrugated horizontally, of another steel; vertical edging at each side of the panel, serving to lock the facing and corrugated sheets together, to provide vertical stiffness, and to snap onto the prepared studding. An asbestos lining, 1/32-in. thick, assists in sound-deadening and heat insulation. The metal members are run through the No. 1 system separately, then are assembled into panels and the exterior surface is applied in the No. 2 system.

Holes are punched into the edges of the facing sheet at the same time that the crown is rolled into it, and these holes are used to suspend the sheet from hooks when it is dipped for the primer coat. The corrugated sheet is similarly handled. The conveyorized handling of the steel members takes them through the first system, which starts with a bonderizing treatment in a dip bath.

Coming from the bonderizing bath, the sheets are dried in a hot air oven maintained at 250 F. These are gas fired. A primer coat is applied in a dip tank, the conveyor system being so arranged that the sheets are automatically immersed for one minute, and raised for draining for one minute. The primer coat is a red oxide primer for sheets intended for architectural and industrial applications in general. Panels intended for government marine work are primed with zinc chromate. The prime coat is baked by passage through a gas-fired oven maintained at 380 F, and baking time is 40 min.

It is in the No. 2 system that the newest installations have been made. The facing sheets, backing sheets, edging strips, and asbestos lining are assembled into panels at the start of the No. 2 conveyor system, and the panels are moved automatically for the remainder of the process. In this system the surface coats are applied, completing the panel.

The first procedure is a wire brushing to clean and slightly roughen the exterior surface of the panel. The work moves on a horizontal chain belt, with the panels placed end to end and forming a continuous length of surface to be coated. Automatic shut-offs at each spray booth stop the spray guns if the conveyor stops.

In the first spray booth two guns spray a double coat of base paint on the exterior surface of each panel, regardless of whether it is to be wood grained or enamelled later. The base coat is dried in an infrared tunnel, in which are installed eight banks of lamps, with 48 lamps in each bank. The lamps used are of 250-watt size. The conveyor has been made

double width at the entrance to the tunnel to reduce the size of the infrared installation.

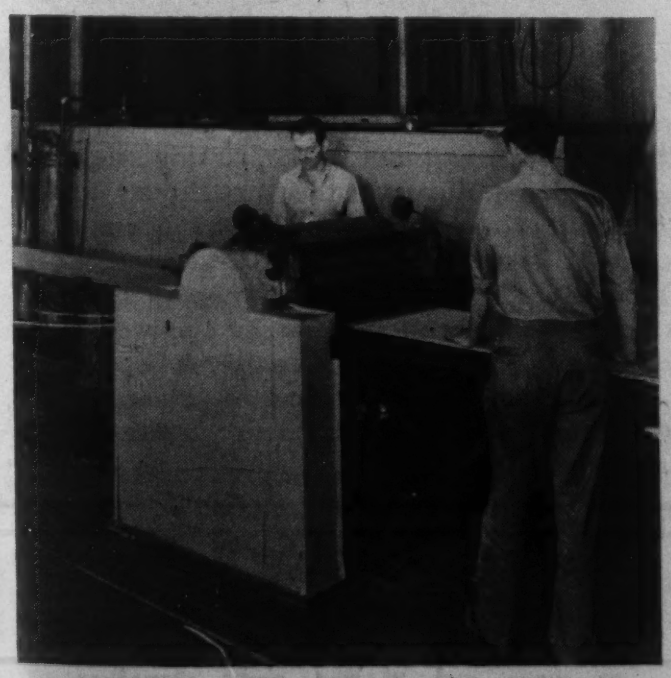
At the exit end of the tunnel the panels pass through the blast from air jets to cool them. An air curtain reduces their temperature to that of the surrounding air, and the conveyor takes them to the jelly roll. Here the desired wood grain is printed on the surface by the offset method. Those panels for which an enamelled surface is intended travel by the jelly roll on an underpass in the conveyor system.

The wood grained panels are then taken into two successive spray booths, where a coat of clear lacquer is deposited by the single gun in each. Drying in an infrared tunnel follows, and after cooling the panels are given a final visual inspection. Panels receiving an enamelled finish bypass the jelly roll, as described, and are taken into the same spray booths at a time when these booths are set up for spraying enamel instead of clear lacquer. The only changes that need be made in the entire system when changing from wood grained to enamelled panels are to bypass the grain printing and to feed enamel to the final spray booths instead of clear lacquer.

The panels are finished in mahogany, light walnut, burl walnut, blond and natural maple, and curly maple as standard items, and enamelled finishes in 16 colors, from ivory to gray, are available.

Electrostatic Spraying in Three Booths

Electrostatic spraying equipment has been installed in each of the three spray booths in the No. 2 system. For this type of spraying a high voltage grid is placed in the booth, above the work, and is given a negative charge. The spray guns deliver the paint mist between the grid and the work. The work is grounded, and is positive with relation to the grid, while the paint particles take on a negative charge. By the repulsion between like charges the paint is thrown onto the work, and the controlled delivery of the paint mist onto the part being painted greatly reduces the loss of paint that occurs otherwise.



Wood grains on the steel panels are printed on by this machine called the "jelly roll."

The grid is charged at about 100,000 to 130,000 volts, with an amperage of about 3 milliamps on the secondary of the transformers supplying the current. Transformers are oil protected, and are located at any convenient spot adjacent to the booth.

Electrostatic spraying was widely used during the war for rapid application of paint finishes. Most of the items so painted were small, and electrostatic spraying was of especial value because the paint mist was thrown onto all exposed surfaces with little loss. In the case of the steel panels, the area to be painted was much larger than that in most of the work heretofore coated by this method.

The success achieved is reflected in several different sets of comparative figures. With ordinary spraying, 60 gal. of paint was utilized to coat about 500 panels. After adopting the electrostatic spraying method, the same quantity of paint would suffice for about 944 panels. An overall saving of more than ⅓ was reported in quantities of mixed paint used. The saving in paint is also indicated by the cleaner appearance of the spray booths, which now rarely need a cleaning.

The overall savings made by the modernization of the No. 2 system, including the changes in the drying tunnels, include a decided saving in labor costs. Whereas 21 men were required to operate the system before the changes were made, the present force consists of only eight men. With this decreased force production has been increased 25%. Floor space needed for the present system is ⅓ less than that required for the previous arrangement.

The quality of the work has been consistently high. As much of the product goes into marine applications, for hospital ships and as Class B bulkhead aboard merchant ships, it is subject to the corrosive effects of salt air. Results in this service have been highly satisfactory.

With passage through a second infra-red tunnel, the finish coat is dried and the panel finished.

Good and Bad Structures in Machining Steel

by NORMAN E. WOLDMAN, Ph. D., *Consulting Metallurgical Engineer*

THE MACHINABILITY RATING OF STEEL depends not only on its chemical composition, toughness and hardness, but also on its microstructure. Two shipments of steel of exactly the same chemical composition range and hardness can have marked difference in machinability, depending upon their difference in microstructure. Furthermore, the microstructure of a certain grade of steel that offers optimum machinability for one type of operation may offer difficulties for another type of operation.

All grades of steel can be purchased with a fine, medium or coarse grain size. They can be purchased hot rolled, hammer forged, pressed or cold drawn. They can be purchased full annealed for laminated-pearlitic structure, normalized for fine pearlitic or sorbitic structure, spheroidize-annealed for spheroidized structure, or quenched and tempered for a fine spheroidized condition. They can also be obtained in any desired hardness range within certain practical limits. And since the microstructure of the steel depends on the type of mechanical working and character of heat treatment given to the steel during mill processing, it therefore becomes obvious that for a given steel of specified chemical composition and hardness, the structure can vary a great deal in the as-purchased condition, and consequently its machinability rating can vary for a definite machining operation in a specified machine tool with fixed cutting tool, and fixed set-up such as speed, feed and depth of cut.

Machinability generally includes a concept of tool life, surface finish and speed of cutting. Most jobs demand long tool life and high-speed cutting for economy, but at the same time many operations require smooth surface finish. Machinability therefore involves tool life, tool performance, surface finish, machine speeds, feed and depth of cut, character and design of cutting tools, cutting fluid, and also the quality, composition, hardness and microstructure of the steel. Each can be further subdivided as follows:

Material Cut
- Composition
- Grain size
- Melting and casting progress
- Fabrication: cast, forged, drawn or rolled
- Heat treatment
- Properties: tensile strength, ductility and hardness
- Size and shape
- Microstructure

Cutting Tools
- Alloy composition
- Heat treatment
- Hardness and strength
- Design, form, shape, angles

Cutting Oil
- Water soluble, mineral, lard or sulfurized oil
- Cooling properties

Operating Machine
- Type of machine
- Rigidity of tools and work holding device
- Feed
- Speed
- Depth of cut

Machinability can best be measured in terms of cutting speed permitting a definite tool life and producing a desired finish. In practice it is said that those materials which offer the longest tool life with satisfactory finish without regrinding are the most readily machinable or have the highest degree of machinability. Then again, machinability may be defined as the relative ease or satisfaction with which a material is cut by sharp tools in various operations, or it may be said that the most machinable metal is the one which will permit the fastest removal of the greatest amount of material per grind of tool with a satisfactory finish.

Since it is agreed, as indicated above, that there are many variables which may and do affect the performance of a machine operation, strong emphasis must be placed on the metallurgical aspects of the purchased material so as to enable the machinist and set-up operator to eliminate at least one of the most important variables. The machinist, set-up operator or tool design engineer can take care of the machine tools, cutting tool design, cutting oils, feeds, speeds and depth of cut, but they are helpless without the metallurgist to control the quality and the microstructure of the steel released for production.

The overall cry of the machine operator is: "Why does not the new lot of steel machine as well as the previous lot of steel when the machine set-up and the tool set-up have not been changed?" Invariably the answer lies in the difference in microstructure between the two lots of steel.

Presented here are the case histories of several steels to show why they were or were not of the right structure or condition for satisfactory machining.

The following illustrations of the effect of microstructure on machinability rating and surface finish are taken from actual case histories in production operations.

Low Carbon Steels

For Electrical Uses

Low carbon steels are used for certain generator, motor and other electrical equipment parts, such as yokes, armatures, cores, heels and many other items, due to their magnetic characteristics when properly annealed. Ingot iron, Armco iron, Globeiron and other extremely low carbon irons, having about 0.05% maximum carbon content, are preferred owing to their superior magnetic properties over the higher carbon steels. But these low carbon irons or steels are difficult to machine, difficult to drill and especially difficult to tap threads. For this reason the manufacturers will often substitute higher carbon material, such as SAE 1010, SAE 1015, SAE 1115, SAE 1020 or even SAE 1315X, at a sacrifice of high magnetic properties in order to improve machinability and thereby lower manufacturing costs.

The machinability rating increases as the carbon content increases to about 0.3% and then decreases. Cold drawn material or quenched and tempered material or even normalized material would improve the machinability extensively, but the material must be in the high annealed condition to maintain maximum magnetic characteristics.

Ferrite is a soft, ductile material and is easily cut with little wear on the tool. Yet it is tough and easily deformed, so that it tears away from the stock, leaving a rough surface. It adheres to the cutting edge of the tool, creating excessive friction heat and drawing the temper of the tool. It has a marked tendency to produce a large built-up edge, that is, welds itself, on the cutting edge. The laminated structure of pearlite is quite rigid for the soft ferrite layers prevent the hard carbide plates from breaking while the latter prevents the former from deforming. Size of these lamellar pearlite grains affect the freedom of machining and type of finish produced. Machining through the pearlitic grains may be readily imagined as a composite of tearing of ferrite and breaking of the carbide plates.

The addition of sulfur or other elements which are capable of forming insoluble intermetallic chemical compounds in the steel will improve machinability and surface finish markedly. These insoluble particles act as chip breakers.

In the machining of machinery parts for other applications it is best to specify cold drawn material with small grain size for optimum machinability. The smaller the grain size of the low carbon steels, the better the machinability. And the higher the hardness the easier the stock is to machine.

Carburizing Steels—Plain Carbon

Free Cutting Steels

In machining cold-drawn, free-cutting, low carbon

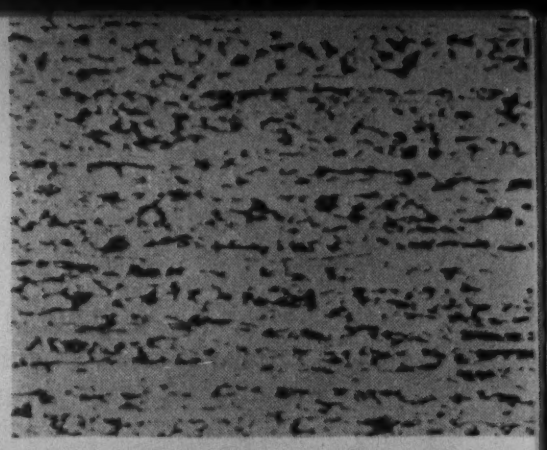
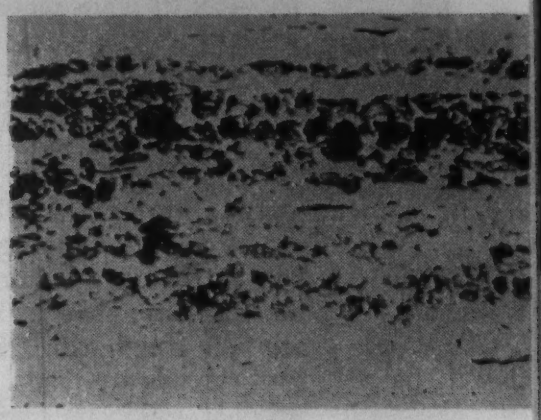


Fig. 1—Good and bad structures for a typical free-cutting carburizing steel.

Leaded 1115—Cold Drawn: Slight banding but uniform, well distributed ferritic and pearlitic areas (X100). Easy-Machining



Leaded 1115—After Carburizing, Before Hardening: Coarse ferrite segregation and banding. Soft ferrite tears, forms built-up edge on cutting tool (X100). Tough-to-Machine

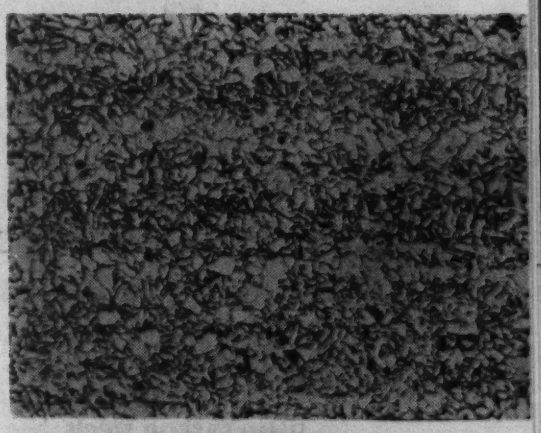
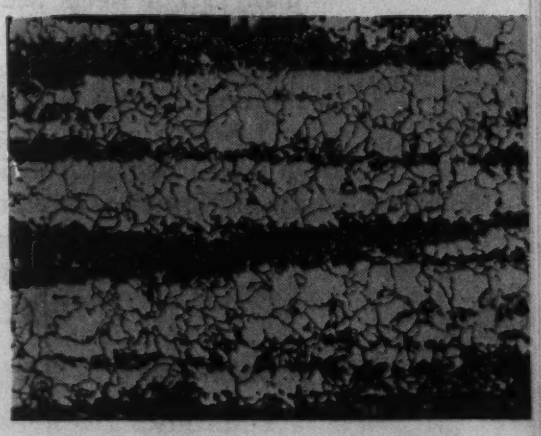


Fig. 2—Good and bad structures in a typical alloy carburizing steel.

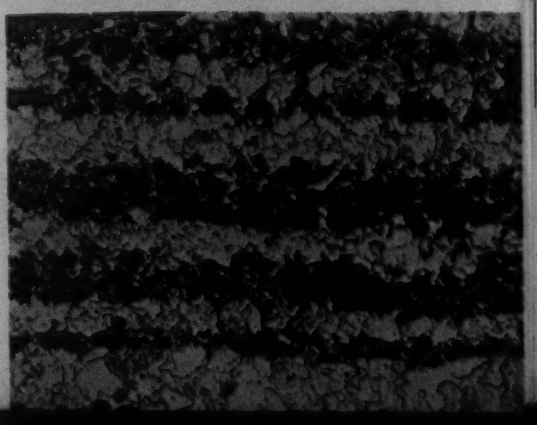
SAE 2515 — Normalized and Annealed: Uniform, fine, equiaxed grain (X100). Easy-to-Machine



SAE 2515 — Improperly Normalized and Annealed: Banded Structure. Harder-to-Machine

Fig. 3 — Typical good and bad structure in alloy carburizing steels.

SAE 4615 — Normalized and Annealed: Desired structure for all alloy low-carbon carburizing steels (X200). Easy-to-Machine



SAE 3312 — Normalized and Annealed: Typical undesired structure often found in alloy low-carbon carburizing steels (X100). Tough-to-Machine

steels such as SAE 1112 or the leaded 1115 in the automatic screw machines, no trouble is ever encountered. The small grain size, the distorted grain, the high internal stress and the presence of the insoluble particles of manganese sulfide or lead, also the higher hardness, all tend to make the material free-cutting and easy to machine at high speeds and high feed. But often the parts are scheduled to be case hardened after machining, and here difficulties are frequently encountered when the parts are to be finish machined after carburizing and before hardening. The troubles are in drilling, tapping, thread cutting or taking light cuts in the uncarburized areas or underneath the carburized case, that is, in the core material. The cuts are very rough, drills and taps jam, and imperfect or torn threads are made. Of course, the hardness of the original stock is lowered after going through the carburizing heat, but not sufficient to account fully for the troubles encountered.

By noting the microstructure of the material after the carburizing heat, the engineer or metallurgist responsible can immediately notify the production department to take remedial measures before setting up the parts for the next machining operation. (See Fig. 1.)

Alloy Carburizing Steels

It is similarly necessary to avoid banded structures with heavy ferrite segregation in such steels as SAE 2515 and SAE 4615, although tearing of the free ferrite during machining will be not so great as in plain carbon steels. See Figs. 2 and 3.

Machining troubles with the banded structure will be particularly noticeable in light cutting, drilling, tapping, thread cutting (especially chasing), reaming and broaching. The magnitude of the rough surface in machining such structures will vary with transverse machining or machining parallel with the axis of the bar. For example, broaching and reaming run parallel to the axis and will badly tear the surface of a tool taking light cuts through the carbon-free iron bands.

Machining the Carburized Case

Difficulties are sometimes encountered in machining the carburized case, after carburizing and before hardening; the cutting edge of the tools wear down faster than normal and may even chip. This may be caused by a structure which contains divorced pearlite and massive segregated areas of carbide (cementite) and ferrite rather than the desired evenly distributed pearlite surrounded by thin carbide envelopes. (See Fig. 4.)

To eliminate this possibility, it is best to put samples of the purchased material through a carburizing heat and examine them under the microscope before hardening and before releasing the material to the production department; all material showing the undesired abnormal structure should be rejected.

Mild, Medium Carbon Steels

Machinery gears are machined from hot-rolled bars, cold-drawn bars, hammer forged bars, or from upset forgings. Some gears are cast to shape and then finish machined. Differences in machinability arise from one operation to another, especially as between hobbing of gear teeth and cutting them in a Gleason or Fellows Gear Shaper. Differences in machinability will also be noticed in broaching and reaming operations where very light cuts are taken. (See Fig. 5.)

In the manufacture of bolts, studs, shafts, gears, pinions and other highly stressed parts which do not require a higher heat treated hardness than 46 Rockwell C, mild or medium carbon low alloy steels are used—such steels as SAE 2330, SAE 3135, SAE 4640, NE 8635 and similar alloys. Here again, even though the hardness of the purchased annealed stock is within the specified range, the difference in microstructure will affect the machinability rating and surface finish, depending upon the type of machining operation.

One aircraft parts manufacturer uses a standard structure sheet to guide the laboratory in passing judgment as to which structures are acceptable for efficient machining. Such standards for each alloy steel save machining costs and avoid production delays. Material having a microstructure found by past operating experience and shown by these standard sheets to be unsatisfactory for optimum machining is rejected even though everything else about the steel including its hardness is satisfactory.

In Fig. 6, (A) shows the desired structure of uniform, equi-axed, moderate grain size for best machinability in all machining operations, whether it be rough heavy cutting, light finish cutting, gear cutting, broaching, drilling, threading or chasing. (B) is similar to (A) but has a much smaller grain size. This fine grain size will produce excellent surface finish, but less pieces per grind of tool. More heat will be developed in machining with subsequent quicker tempering of the cutting edge. Although it may be accepted and it usually is, in order to keep production going, yet it is really not desired. In lower carbon steels the finer the grain size the better the machinability because the material with the finer grain size is usually harder and less ductile. This greater hardness and lower ductility are desired for steels having a large amount of free ferrite, as in the very low carbon steels. But in the mild and medium carbon steels, too fine a grain size will develop more heat in machining with subsequent more frequent grinding of the tools, and decreased production rate.

(C) shows the undesirable duplex structure which may or may not affect tool life but will affect surface finish. The greater the amount of this duplex structure the more undesirable the steel. Of course, such a structure should be rejected at any rate to protect the heat treating department as it is bound to cause more distortion in hardening than when the duplex structure is not present in the steel. (D) again shows the undesirable marked banding which will definitely affect tool life and will produce a rough and torn surface, depending on the kind of machining operation and whether the cutting is transverse or parallel with the axis of the bar. The discussion of the troubles encountered with banded structure was given above.

(E) shows the structure having too coarse a grain

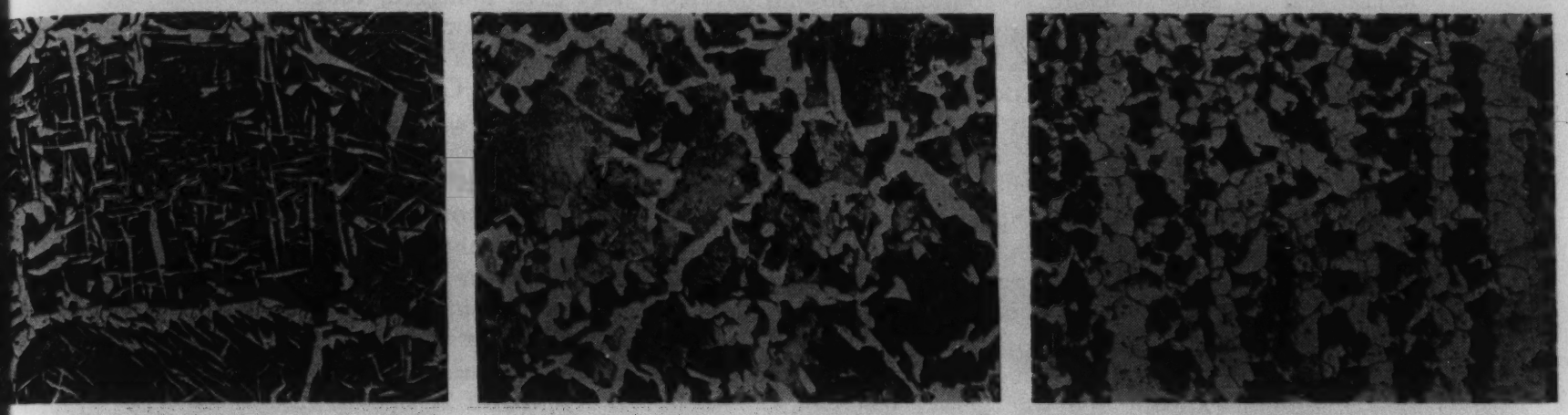
—Good and bad structures after car-ng but before hardening of a typical low-alloy carburizing steel.

. NE 8620—After Carburizing, Before ning: Normal desired structure, well dis-ed pearlite (black) surrounded by thin bide envelope (X500). Easy-to-Machine

B . . . NE 8620—After Carburizing, Before Hardening: Abnormal, undesired structure. Massive segregation of ferrite and carbide (X500). Tough-to-Machine

A *B*

Fig. 5—Differences in structure of SAE 1045 steel as a result of the forming method.

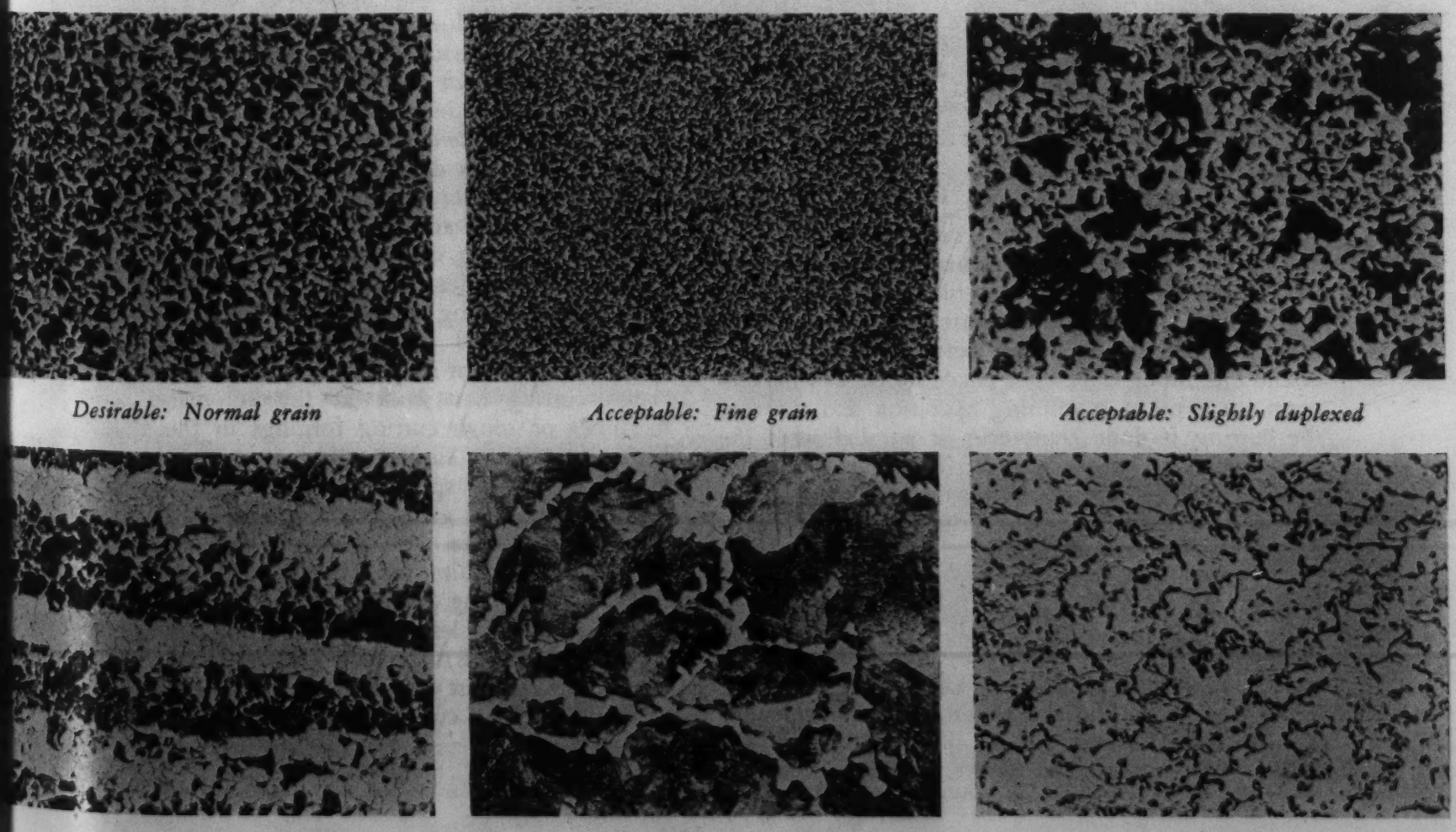


Cast: Ferrite needles within the pearlite ns and envelopes of ferrite around the lite grains. Grains are equiaxed and coarse (X100).

Upset-Forged: Broken envelopes of ferrite around the smaller pearlite grains. The structure is uniform in all directions (X100).

Hot-Rolled: Uniform, fairly equiaxed structure with a tendency toward banding with the ferrite and pearlite lined up in alternate layers or bands (X100).

. 6—A standard structure sheet used by one manufacturer to check on suitability for machining of a medium-carbon alloy steel (SAE 3135). Normalized and annealed, X100.



Desirable: Normal grain

Acceptable: Fine grain

Acceptable: Slightly duplexed

Not acceptable: Banded

Not acceptable: Coarse grain

Not acceptable: Spheroidized

size. Such coarse grain steel will not machine as freely as the smaller grain size steel owing to the large areas of pearlite which contain about 0.85 to 0.90% carbon, and through which the cutting tool must pass. It is true that the larger the grain size the better the machinability, but only up to a point where the grains become abnormally large and the ferrite exists as thin envelopes around the coarse pearlite grains. Then again, the abnormally large grain size will introduce heat treating troubles by making the material more susceptible to deformation during hardening.

(F) shows the same alloy steel having a spheroidized structure, in which the pearlite is divorced into globules of iron carbide distributed throughout the ferrite matrix. This structure is undesirable for all machining operations, although it may not offer much trouble in roughing operations in the automatic screw machines. But it is practically impossible to obtain satisfactory surface finish when taking light cuts, or when threading, chasing, broaching and gear cutting. Surface finish is a relative term, as it depends on the standards set up by the inspection department. But, irrespective of the standards, visual examination of the surfaces will always show a rougher and a more ragged surface than when machining a structure similar to that shown in (A).

Steels of 0.30 to 0.40% carbon content gave us our greatest troubles during the war period when purchased from warehouses. When mill quantities were purchased direct from the mill it was a simple matter to obtain the steel with the desired microstructure as per specification. But such steel bars from warehouses were invariably found to be from 25 to 100% spheroidized. As a result, the rejections due to poor surface finish ran excessively high for warehouse material. This was especially true for cold-drawn bars of small diameters purchased for threaded bolts, studs and screws. Most of the rejections were on poor finish and tears in the threads. The larger size bars gave trouble in broaching and cutting gear teeth on Gleason or Fellows Gear Shaper.

Acceptable Degree of Banding

Fig. 7 shows three microstructures of SAE 3135 steel with different degrees of banding, and is the standard sheet to determine acceptance or rejection. (A) shows the desired structure with no banding, (B) shows the acceptable structure with slight banding, and (C) shows the structure with the rejectable marked banding. As stated before, the magnitude of the machining difficulties encountered will depend upon the type of machining operation and whether the cutting is done transverse or parallel with the axis of the bar stock. The ferrite streaks in coarse banding will be sluggish in cutting and will tend to adhere to the cutting edge of the tool, thereby producing torn or ragged surface.

Harder Medium-Carbon Alloy Steels

In machining the low alloy, medium carbon steels, such as chromium-vanadium SAE 6150, nickel-chromium SAE 3250 and nickel-chromium-molybdenum equivalent to SAE 4350, in which the carbon content is above 0.45%, practical experience has shown that there is a very close relationship between the microstructure and machinability. This relationship holds the same for all three of these steels and also for other alloy steels of different composition but with a carbon content above 0.45%.

The steel which machined the best in the automatic screw machines had a coarse spheroidized structure, while the steel which was more difficult to machine had a laminated pearlitic structure. It was also observed that the fine, close-grained structure dulled the tools more readily and developed more heat during machining than the coarse, open-grained spheroidized structure. In broaching it was observed that spheroidized steel gave a ragged, rough and often a torn surface, while a sorbitic or a laminated-pearlitic structure produced a smooth and clean surface. In gear cutting on the Gleason or Fellows Gear Shaper it was observed that a spheroidized structure produced a rough surface with burrs on the tooth end, while a laminated-pearlitic structure produced a clean, smooth surface with no adhering burrs. This information brought the realization that the efficiency of one machining operation must be sacrificed for the efficiency of another machining operation, or that a compromised structure must be accepted so as to obtain the most economical overall machining.

In any rough cutting operations the coarse, open-grain spheroidized structure gives the longest tool life and the least amount of generated friction heat. Of course, in such operations surface finish is not important and the major factor is tool life and speed of cutting. For all machining operations where light cuts are taken, such as in broaching, reaming, threading, gear cutting and so forth, the spheroidized structure is undesirable as it produces rough, torn surfaces which will not pass inspection and may be scrapped or salvaged by additional operations to smoothen the surfaces. A fine, close-grain spheroidized structure is better than a coarse, open-grain structure. But the desired structure for light cuts is the laminated-pearlitic structure as the surfaces produced are smooth and clean with little or no burring.

Fig. 8 shows six different microstructures for SAE 3250 nickel-chromium steel used as standards to determine the suitability of observed structures for specific machining operations. These structures and their machinabilities hold for all low alloy, medium carbon steels having more than 0.45% carbon. (B) shows the desired coarse, open-grain spheroidized structure desired for roughing operations whether it is rough cutting bar stock in the automatic screw machines or rough cutting forgings in the Bullard Mult-Au-Matic or similar machines. (A) shows the finer, close-grain spheroidized structure which is passable but will generate more friction heat and shorten the tool life. (F) shows the laminated-pearlitic structure best suited for all light cutting operations, especially broaching, threading and gear cutting. This structure offers the least machining economy in roughing operations. (E) shows a 75% laminated structure, which is about on the border line for acceptable structure for light cutting, while (C) shows a 25%

7—Standard structure sheet showing acceptable and unacceptable banding in SAE 3135 steel for machining. Normalized and annealed, X100.

Desired: Not banded

Acceptable: Slightly banded

Not acceptable: Severely banded

8—Suitability of various microstructures of medium-carbon alloy steels (represented here by SAE 3250) for different machining operations (X750).

100% Spheroidized-Fine: Passable for rough cuts

100% Spheroidized-Coarse: Best structure for rough cutting

25% Laminated: Passable for heavy rough cutting

50% Laminated: Barely passable for either finish or rough machining

75% Laminated: Passable for light cuts

100% Laminated: Best structure for light cutting

Fig. 9—Different degrees of machinability represented by typical structures found in SAE 1095 steel (X500).

Completely Spheroidized: Ideal structure for either roughing or finishing cuts

Finely Divided (Sorbitic) Pearlite: Poorest structure for efficient machining

Laminated Pearlite: Intermediate in value

laminated structure, which is about on the border line for heavy, rough cutting.

For these steels it is not practical to obtain one microstructure to have the optimum machinability for all types of rough and finish machine operations. In the manufacture of gears and similar parts it is best to purchase the bar stock or the upset forgings in the 100% coarse, open-grain spheroidized structure similar to (B) in Fig. 8, or as close to it as possible as shown in the border limit cases in (A) and (C). The cut-off blanks can then be either box-annealed or cycle-annealed to convert the spheroidized structure into the laminated-pearlitic structure, similiar to (F) in Fig. 8 for light cut and finish machining operations such as broaching, threading, gear cutting and so forth.

Where the set up is such that box-annealing or cycle-annealing cannot be done, either because of lack of heat treating equipment or because there are one or more finished dimensions in the automatic machining operations, then a compromise can be made by purchasing the raw stock in a 50% laminated structure as shown in (D) in Fig 8. Such a structure, however, will force sacrifices in the efficiency of both rough cutting and finish cutting operations.

High Carbon Steels

High carbon steels for machinery parts, tools, dies and springs contain from 0.7% to over 1.0% carbon. The structure of these steels, as purchased, can vary as in the lower carbon steels. The ease of machining and the machinability rating will again be determined by the microstructure, assuming that the material is within the hardness range specified. And the microstructure is determined by the heat treatment given to the steel after mechanical processing at the mill.

Fig. 9 shows three typical microstructures of SAE 1095 steel, illustrating what can be obtained from the mill for high carbon steels ready to be machined. (A) shows the completely spheroidized structure which is desired for easiest and best machinability rating. This structure is ideal for both roughing and finishing cuts. There is sufficient carbon and sufficient number of carbide spheroids to toughen the matrix and prevent the tearing obtained when machining the lower carbon steels in the spheroidized condition. (C) shows the completely laminated-pearlitic structure which will machine with a somewhat smoother surface, but will develop more friction heat with subsequent shorter tool life. (B) shows a sorbitic-pearlitic structure, in other words a finely divided pearlitic structure, which is harder to machine and will develop more friction heat than either of the other two structures. This sorbitic structure is not desired for economical or high-speed machining.

The foregoing applies to any high carbon steel whether alloyed or not.

General Conclusions

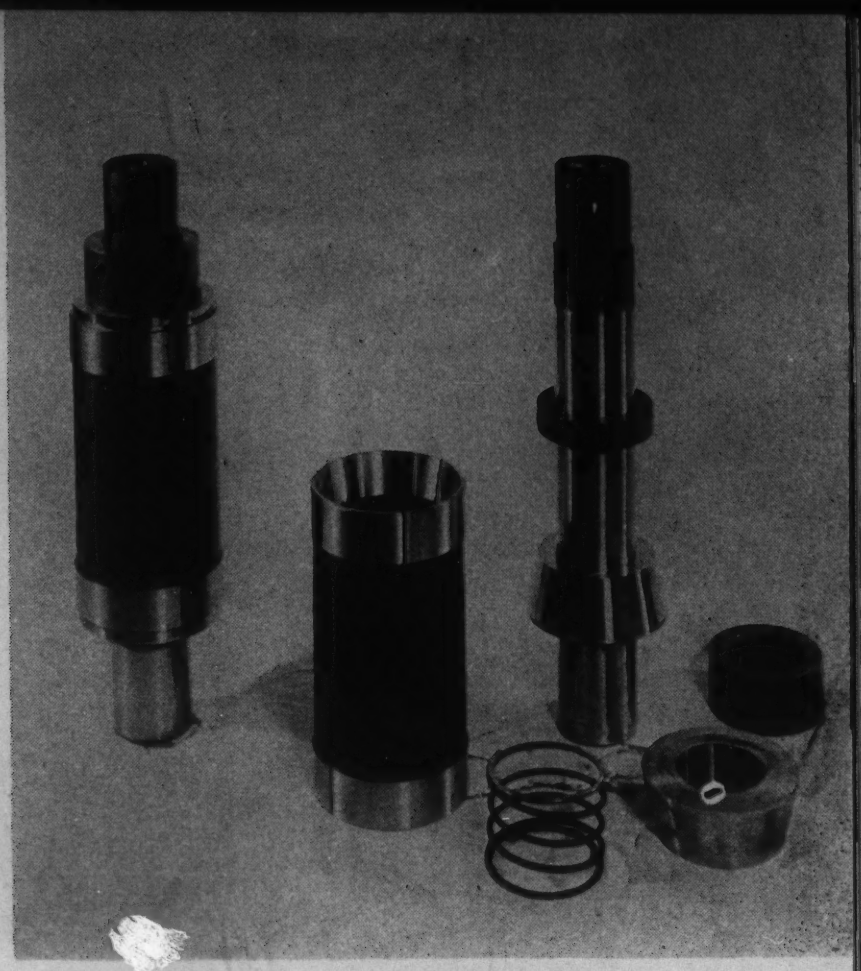
Machinability rating depends upon so many different factors and on so many variables that one finds it rather difficult to operate a machine shop without constantly encountering trouble of one sort or another. Only the combined thoughts of the metallurgist, the production operator and the tool design engineer will quickly solve all the troubles and keep production going with minimum delays. The factors affecting machinability are the material being cut, the cutting tool material, the cutting tool design, the cutting oil, the machine tool, and the feed, speed and depth of cut taken. In addition, there are a number of variables in each one of these factors which have to be under control.

A study of the microstructure of the material being machined has shown that there is a strong relation between the microstructure of the material and its machinability rating. The points brought out in this article are the following:

1. Machinability increases in general with carbon increase up to about 0.3% and then decreases.
2. Ferrite is a soft, ductile material, and is easily cut with little wear on the tool. Yet it is tough and easily deformed so that it tears away from the stock leaving a rough surface. It also adheres to the cutting edge, creating excessive frictional heat and drawing the temper of the tool.
3. Pearlite is quite rigid when laminated and the size of the grains affect the freedom of machining and type of finish produced. The tool cuts across the alternate plates of hard, brittle iron carbide and soft, ductile ferrite.
4. Spheroidized pearlite consists of round carbide globules in the soft ferrite matrix with the result that the hard globules are pushed away by the cutting tool without much wear. The cutting tool does not cut through the spheroids.
5. The very low carbon steels are best machined in their normalized or air cooled condition, or in their cold-drawn and strain-relief condition. The higher the hardness and the smaller the grain size the better the machining.
6. Mild steels machine the best when in the normalized and annealed condition and having a uniform laminated-pearlite structure. A spheroidized structure will produce a torn and ragged surface. The laminated structure is desired for both rough and finish cutting.
7. Medium carbon steels of carbon content over 0.45% should have a coarse, open-grain spheroidized structure for all roughing operations with heavy cuts, and should have a laminated-pearlitic structure for all finishing operations requiring very light cuts. When taking light cuts on a spheroidized structure, the surfaces will tear and will be rough and ragged.
8. High carbon steels should have a coarse spheroidized structure for all machining operations. The laminated structure will produce smooth surfaces, but does develop more friction heat and will dull the tools faster with resulting more frequent regrinds of the cutting tools.
9. Banded structures should be avoided at all times as it will tend to produce rough and ragged surfaces, especially when cutting parallel with the axis of the bar. Ferrite segregation should also be avoided to prevent a built-up edge forming on the cutting tool.
10. A duplex structure of coarse grains adjacent to fine grains should always be avoided.

Tool Steel Tubing

by EDWIN LAIRD CADY



One of the many uses for tool steel tubing is in the making of parts for expanding arbors. (Courtesy: Bissett Steel Co.)

THICK WALLED TUBING made of tool steel first appeared in the United States in 1916. But during the 30 years that it has been sold here this product probably has not been tried even on an experimental basis for more than 1% of its possible uses. It has been handled as a warehouse specialty only, marketed with very little aggressiveness, backed up by a minimum of informative sales literature and of sales engineering. For many a plant engineer, tool maker, maintenance engineer and machine designer tool steel tubing is what Wall Street operators would call a "sleeper."

Gains and savings to be made by its use are varied. There are at least three grades—water hardening, air hardening, and oil hardening—and since not all suppliers tell what analyses they use there may be more than one grade of the oil hardening. Among the advantages are:

1. *Savings on Machining and Materials Costs.* Tool steels are not inexpensive materials nor are they high in machinability. When the parts to be made are to have bores these tubes can greatly reduce the amounts of metal to be machined off, the machining time, and the amounts of metal wasted in scrap.

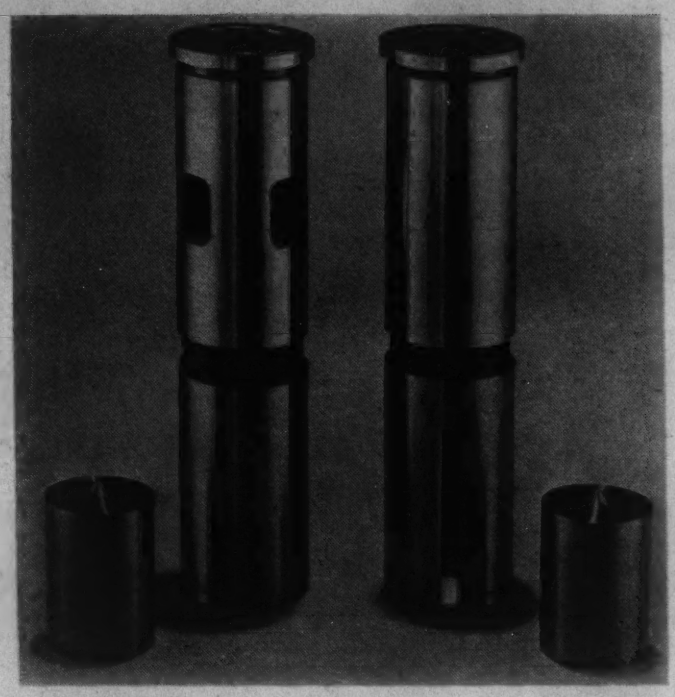
2. *Increased Resistance to Abrasive Wear.* Processes by which tool steel tubes are made include piercing, hot rolling, and extruding. The process depends largely upon the diameter of the tubing and upon steel mill production problems. Each of these processes includes a great deal of working of the metal, with the result that grain structures are compacted much as they would be if the product were forged. The tubing therefore is high in abrasion resistance. No figures seem to have been compiled to show just how the tubing compares to other forms of tool steel in this respect. But in some instances parts made of tool steel tubing and exposed to abrasive wear have had double the service lives of similar parts made of other tool steel forms but of the same metallurgical analyses.

3. *Multi-Directional Strength.* The working of the metal in the processes of manufacturing imparts uniformity of multi-directional strength to the tubing as compared to the tendency toward mono-directional longitudinal strength so often found in other forms. In short, the strength is likely to be more nearly equal in all directions in the tool steel tubing as compared to bar stocks and some other forms in which the strength may be high in the lengthwise direction and much lower in the crosswise direction. Figures are lacking as to just how the tubing compares to other forms of tool steels of the same analyses, and especially to ring forgings, in this respect. But where the stresses imposed on parts have been such that multi-directional strength has been important, as for example in the making of dies which have very thin sections contiguous with heavy ones, there have been instances in which tool steel tubing has proven itself superior.

Many parts now machined from solid tool steel could be made from tool steel tubing which is available in oil, air and water hardening grades.

4. *Hardenability.* Its compacted grain structure and its uniformity of directional strength permit tool steel tubing to be given closely controlled hardnesses, to be hardened to wide ranges, and to be heat treated at widely varying temperatures, all with a minimum of warping and an avoidance of damaging residual stresses. Its hardness can be held within close limits. Or if desired it can be treated roughly in the hardening processes and still emerge as a good product. Rockwell C overall range is 60 to 67 as quenched.

5. *Corrosion Resistance.* Some grades of tool steel tubing contain 11.5% of chromium. This is only one half of one per cent below the 12% bottom limit at which steel is defined as stainless. These grades, then, are "mildly stainless" and have corrosion resistances far above those of straight carbon steels. But this applies only to some grades. Not all tool steel tubing grades contain chromium.

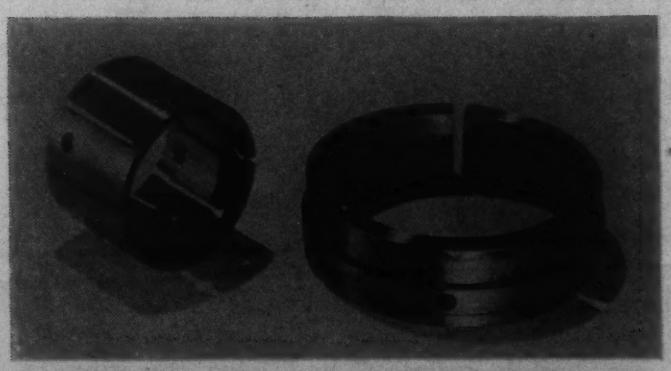


Tool steel tubing is valuable for parts which are subject to abrasive action in service such as these toothpaste tube filling parts. (Courtesy: Bissett Steel Co.)

Wide Range of Sizes

Tool steel tubes are made in standard stock sizes ranging from 7/8 in. o.d. x 3/8 in. i.d. to 16 in. o.d. x 12 in. i.d., with size increments in the most popular size ranges running as small as 1/64 in. Nearly all requirements thus can be secured from sizes carried in warehouse stocks. In addition, special sizes up to 20 in. o.d. are supplied on order. In the near future the ordinary range of special sizes is expected to be increased to 30 in.

Prices vary. One warehouse management said that on its standard sizes the cost is just about five cents a pound more than for bar stock of the same o.d. and same analysis, this statement applying only to oil hardening grades. Of course, on a per lineal foot of the same o.d. basis, or on the basis of the amount of steel bought to make a given number of finished parts, this is a much lower price than for solid bar stock.



Shown here are an expansion ring and a 3-piece collett bushing, both made of tool steel tubing. (Courtesy: Bissett Steel Co.)

Another warehouse management states that, for a given o.d. and i.d., if the water hardening grade cost $1.00 for a nominal number of pounds then for the same quantity the oil hardening might cost about $1.25 and the air hardening about $2.00. Such figures are sufficient only to give a very general idea of costs ranges.

Special sizes vary in accordance with their production costs. In general, the thinner the wall for a given o.d. the higher the production cost and therefore the higher the price.

As is common warehouse practice, standard stock sizes can be bought cut to short lengths, there being the usual kinds of price extras for this. Most tool steel tubing is sold in the annealed condition, but if desired the oil hardening grade can be bought fully heat treated at an extra cost.

The Bissett Steel Co. carries only an oil hardening grade and has its warehouses in Cleveland, Ohio.

A. Milne & Co. carries an air hardening grade (carbon 1.55, chromium 11.50, molybdenum 0.75), an oil hardening grade (carbon 0.90-0.95, chromium 0.50, tungsten 0.50, manganese 1.00-1.25) and a water hardening grade (carbon 1.05-1.15), in warehouses in Boston, Chicago, New York, Philadelphia, Pittsburgh, Washington, Cleveland, Rochester, St. Louis, Hartford, and Bridgeport.

The Bissett oil hardening grade may or may not be of the same general analysis as the Milne one.

There may be other steel warehouses carrying tubular tool steels of these or other analyses.

The engineer, then, has his choice of three grades of tubular tool steels:

1. *Water hardening,* selling at the lowest price, hardenable to 63 to 66 Rockwell C as quenched, having the highest machinability of the three, containing no chromium and therefore not stainless at all, suitable where surface hardness with a tough core is desired. It is low in red hardness, good in impact value, high in compressive strength.

2. *Oil hardening,* selling for about 25% more than the water hardening, hardenable to 65 to 67 Rockwell C as quenched, having 80% of the machinability of the water hardening, low in red hardness, good in impact value and in compressive strength, containing a little chromium and therefore a little more corrosion resistance than the water hardening, suitable for resistance to abrasive wear, especially recommended for low shrink and distortion in hardening. A "non shrink" steel.

3. *Air hardening,* selling for about 100% more than the water hardening, hardenable to 64 to 65 Rockwell C as quenched, having 55% of the machinability of the water hardening, better than medium in red hardness, good impact value, excellent compressive strength, containing enough chromium and therefore corrosion resistance to just miss being a stainless steel, high in resistance to abrasive wear, low in hardening distortion, especially recommended for resistance to abrasive wear and to corrosion.

The hardened case depth is better than medium in the water hardening but is deep in both the oil and the air hardening grades.

Varied Uses

Some of the uses for which these steels have been found successful include:

Arbors, especially the expanding arbors. These are long as compared to their diameters. Drilling out solid bars to make them would require considerable waste of metal and of machining time.

Bearings and bearings races. These alloys do not contain the metals which are generally considered likely to spall or to gall when used in bearings or as hard bushings.

Bushings for jigs, guides, bearings and other wear parts. The air hardening steel has been used with success where abrasive and frictional wear may be promoted by exposure to mild solutions of acids and other chemicals.

Cams and cam followers. Most of these have bores, all must be resistant to frictional wear, many must also resist abrasion, impact and corrosion.

Colletts, especially spring types. It commonly requires very little wear to destroy the accuracy of a collett. These steels have the necessary resilience for spring colletts.

Cutting edges, circular cutters for metals, cutters of various types for such abrasive materials as ordinary papers, laminates, plastics, even for papers coated with abrasives. Here these steels have one of their most important fields.

Dies and die parts. Here the list of successful applications is longest, so long that tubular tool steels often are called "hollow die steels." The list includes ring dies, impact extrusion, tube, cold draw bench, blanking, forming, stamping, lamination, silicon sheet blanking, and so on.

Rings for wear resistance on all sorts of mechanisms.

Rolls. This list also is long. Feeder rolls for wire machines, Medart (straightening) rolls, leveler, soap crushing, ceramic crushing, paper trimmer, plenty of others. When cooling water or other liquids are to be conducted through rolls the air hardening grade with its corrosion resistance is especially good.

Saws. Splitting saws for paper products, plastics, metals.

Shafts and spindles, especially those which must be highly accurate, have interior or exterior contours difficult to produce and destructible with very little wear, require considerable stiffness, must be low in the age distortion that can be caused by residual hardening stresses, are to have water or other fluids circulating through them, are to be exposed to abrasive wear or to mildly corrosive agents.

Sleeves which must be hardened.

Valve seats and parts, wherever frequency of valve operation causes unduly rapid wear. These steels have made superior performance records in sludge pump ball valve seats.

There have been dozens of other successful applications in travel parts which are threaded to travel on leadscrews, in pumps, in guides and guide sheaves and rollers, in tool and other supports which must have enduring accuracies. The examples cited here will indicate the general field of service.

Some of the range of sizes of tool steel tubing can be seen in this illustration. (Courtesy: A. Milne & Co.)

Hardening methods are the same as those used for all tool steels of like analyses. These steels are sluggish and require time to come up to temperature and for soaking. But any shop which is familiar with tool steel hardening can harden them without trouble.

Machining and other fabricating also is by methods familiar to every shop which customarily handles tool steels. The carbide tipped tools or the familiar 18-4-1 high speed steels will machine them.

One difference is that band saws are used for a great many operations on these steels. The use of abrasive disks of the kinds ordinarily employed for cutting-off is not carried as far as it could be with profit by some fabricators. These disks can be used for high speed performance of slitting operations on tool steel tubes.

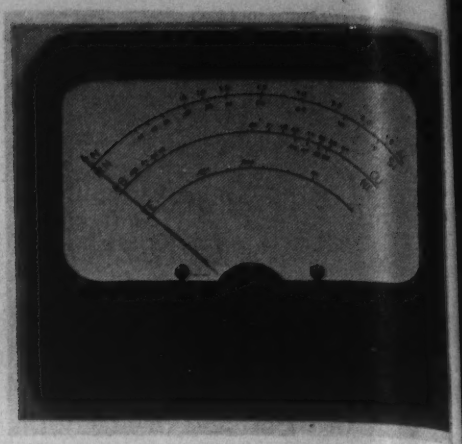
These steels, like all tool steels of their types, are easy to grind. They have little tendency to load up the wheels.

They can be welded or brazed. In some cases they are hardened before welding, and Monel welding rods are used to avoid picking up too much carbon from the steel and causing tendencies to crack.

The surfaces of these steels can be plated with chromium or other materials to reduce wear or corrosion.

Tubular tool steels, then, are well known grades of tool steels which are made in thick walled tubular form. The primary purpose of this form is to reduce fabrication costs when the steels are made into parts which have bores. Incidental to the production of these forms, and perhaps deliberately enhanced in some of these products, the tubular tool steels are given compacted grain structures with multi-directional strengths which result in high resistance to abrasive wear and low distortion in hardening and in specific superiorities for various purposes. Wide lists of stock sizes are available at convenient warehouse points, still wider ranges of special sizes are produced on order, the dimensions available are becoming larger. These steels have not been marketed aggressively. They are capable of solving many problems for which they have not as yet been tried.

Direct reading spectrographic equipment is used by Ford, to check, in a few minutes, all magnesium foundry heats before pouring is to begin.



Quick Analyses of Magnesium Foundry Heats

by F. R. BRYAN and G. A. NAHSTOLL, *Chemical Engineering Research Dept., Ford Motor Co., Dearborn, Mich.*

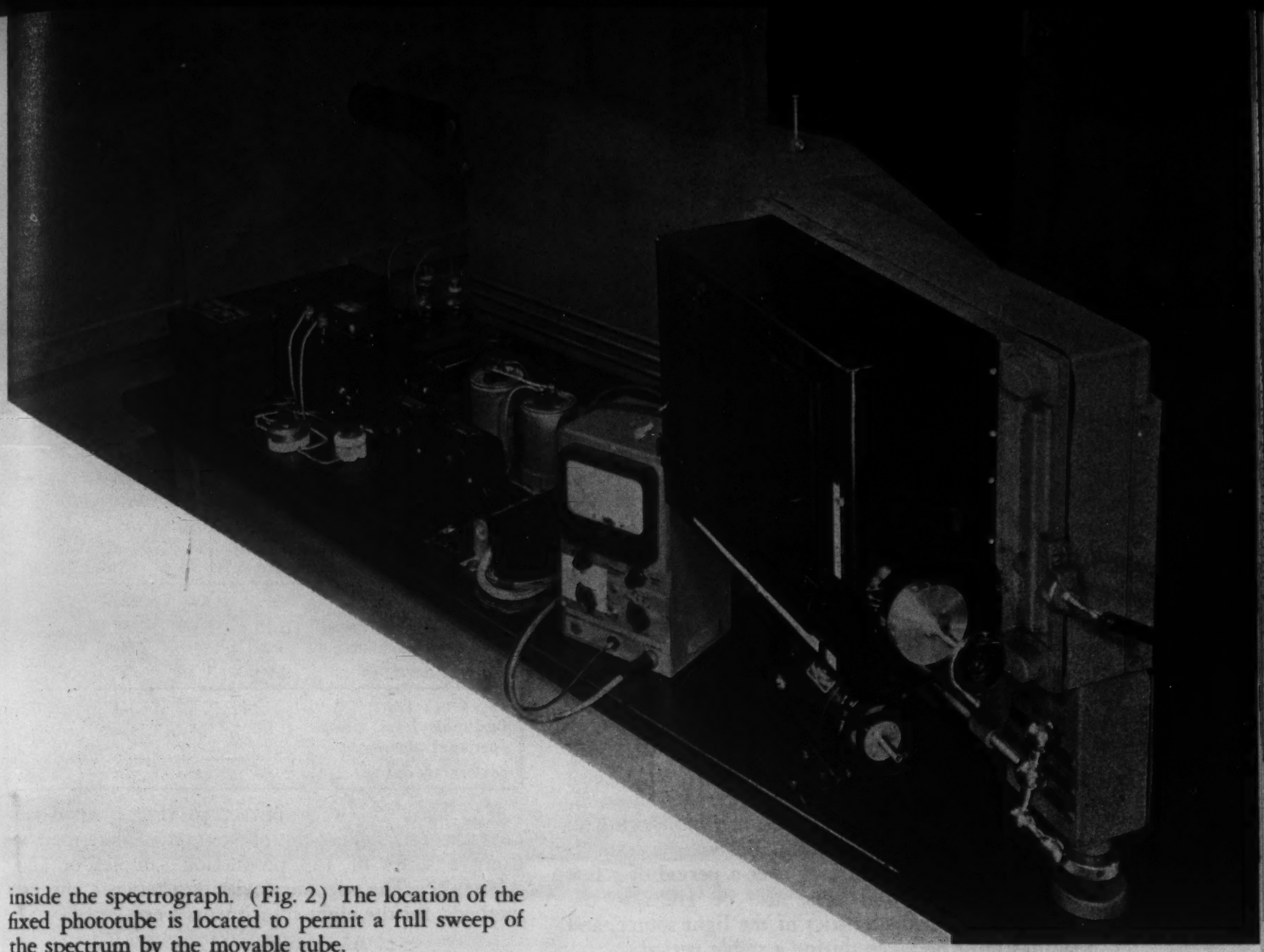
THE ACCURATE ANALYSIS of foundry heats to determine whether alloying elements are present according to specifications, or whether certain impurities are within required limits, is an important part of the procedure insuring satisfactory castings. Control analyses must be made quickly since the cost of holding hot metal is high. In the case of the magnesium foundry it is doubly important that results be obtained as rapidly as possible, since time and temperature of holding are important factors in the control of grain size in the casting.

Combined with this need for quick results is the necessity for handling a large number of samples. While the number of heats will depend upon the size of the foundry and type of equipment it uses, even a foundry of moderate size will find the services of several analysts necessary. Wet methods of analysis are too slow for control of heats before pouring in most cases. The spectrograph, although expensive, has shown itself to be a valuable instrument in that both speed and a large volume of work can be obtained.

While spectrographic analysis by the usual methods, involving photographing spark spectra and determining the quantities of elements present from the intensity of typical lines, affords a considerable saving in time over wet chemical methods, it is still a difficult matter to get results to the foundry while a heat is being held preparatory to pouring. At the Ford Motor Co. a direct reading accessory was developed for the spectrographic control of magnesium foundry heats, making possible results within a few minutes, and the handling of a large number of samples by a single operator. As many as 80 determinations an hour could be analyzed to an acceptable degree of accuracy by one technician, with an additional saving in cost of film and darkroom supplies.

The direct reading spectrographic method of analysis was developed within the Chemical Engineering Research Dept. of the Ford Motor Co. Analyses had previously been made with a Bausch and Lomb medium quartz spectrograph and a Feussner interrupted high voltage spark source using the usual photographic plate processing equipment and a non-recording microphotometer. For the direct reading the spark source was retained without alteration, while the spectrograph was modified by constructing an arrangement of photocells to replace the photographic plate. The processing equipment and microphotometer were no longer required. By placing slits to isolate certain selected lines of the spectrum, mounting one phototube to permit it to be moved into a position before any one of the slits, and using a second tube as a reference, the relative intensity of any selected line of the spectrum was then determined by voltmeter readings. The difference in potential between the movable tube and the reference tube was calibrated to read percentage composition on a meter scale.

The direct reading attachment to the spectrograph consists of three principal parts: (Fig. 1) The first is a rack located in the focal plane of the spectrograph and holding several adjustable width slits in positions corresponding to selected lines in the spectrum. The second is a phototube mounted on a screw and operated by a crank outside the instrument. The tube can be moved into position opposite any slit to receive the emitted light of the desired wavelength. The third is a combination of slit, reflecting device and stationary phototube serving together as an internal standard. This slit is positioned so as to intercept a line chosen as a reference. The reflecting device of glass with an aluminized front surface is mounted behind the slit and directs the light to the second phototube mounted in the scale lamp housing



inside the spectrograph. (Fig. 2) The location of the fixed phototube is located to permit a full sweep of the spectrum by the movable tube.

The slits themselves consist of mounted blades, carefully sharpened and lapped, and adjusted to an aperture such that light of an 100 micron entrance slit can be fully included. Line height is fixed at 10 mm. by the entrance aperture. Two rows of slit assemblies, one above the other, are mounted inside the instrument when analyzing magnesium alloys, and are positioned vertically by movement of the entire rack. The slits are so placed as to intercept suitable lines of aluminum, zinc, manganese, copper, silicon, nickel, iron and lead, which are constituents of the magnesium alloy.

The tubes used are RCA 1P28 multiplier phototubes. They possess high sensitivity and satisfactory response in the wavelength region ordinarily used for industrial emission spectroscopy. The rated current amplification of 200,000 times and the special glass envelope, allowing sensitivity to nearly 2,000 Angstrom units, give it practical advantages over ordinary phototubes and photocells.

Current for the tubes, supplied by full wave rectified and filtered power supply at about 1,500 v., is fed to a tapped voltage dividing resistor. In this way potentials up to 150 v. per stage can be supplied to the nine electron multiplying stages within the tube. In actual use, however, it has been found that increases in steps of 90 v. from the photocathode to the ninth stage are satisfactory. Between the ninth stage and the anode this voltage is doubled, giving 180 v., to permit current saturation at relatively high light values. Voltage stabilization is obtained by the use of a large bleeder current, by a voltage regulating transformer in the primary of the circuit, and finally by the use of a V-R 90 voltage regulating tube across

The dial (upper left) is calibrated to read composition percentages directly. In the illustration above can be seen the spectrograph, meter and power source, while below is the phototube attachment of the spectrograph.

each section of the voltage divider. Both the fixed and the movable tubes are supplied from the common tapped voltage divider of the power source.

The current output of each tube is fed into a 20 megohm resistor. The difference in the voltage drop across the two separate resistors is measured by means of a vacuum tube voltmeter. This voltmeter reading indicates the difference in intensities between the element and reference lines. Since these differences in intensity are proportional to concentration of element, the substitution of recalibrated multiple scales allows the reading of percentage composition directly from the meter. (Fig. 3)

In using the 20 megohm resistance value, the voltage drops are of sufficient magnitude to provide spectral background readings considerably above the phototube dark current reading. The meter, therefore, is fairly sensitive to weak spectral lines and low percentages of elements. A lower resistance lessens the sensitivity of the apparatus for very small light values, and a higher resistance is likely to tax the insulation of the measuring circuit and be of no further benefit to the sensitivity.

Fluctuations of the spectrographic spark cause instantaneous variations in the tube output. Placing an 0.1 microfarad condenser across the voltmeter tends to average these irregularities over a period of a few seconds. Consideration must also be given to the "time of wait" characteristics of the light source, and readings must be taken during a stable period.

Fig. 4 shows a general view of the apparatus including the covered head attachment containing the movable phototube and slits, the electrical power supply to the phototubes and the measuring voltmeter.

Before the method was accepted for production analyses, tests were made to determine the reproducibility of results obtained. Determination of aluminum in magnesium was selected. Using standard alloys, the movable tube was positioned at 2373 Angstroms, and the fixed tube at 3176 Angstroms for reference. The alloys were sparked 10 times over an 8-hr. period without adjusting the instrument during that time. Later, about 15 determinations were made over a period of two weeks, again without adjustment during the time of test. Results were:

	Std. 5.9% Al		Std. 8.7% Al	
Eight-Hour Test:	**Max.**	**Avg.**	**Max.**	**Avg.**
Deviation from mean per cent aluminum	0.15	0.08	0.13	0.06
Per cent deviation	2.50	1.30	1.50	0.70
Two Week Test: Deviation from mean per cent aluminum	0.18	0.12	0.28	0.13
Per cent deviation	3.10	2.00	3.30	1.50

The accuracy of the direct reading method was next checked against the photographic plate method, using a series of 133 production samples of alloy AMS4422. The average deviations between the two methods, for the eight constituents were:

Aluminum	0.17%
Zinc	0.24%
Manganese	0.02%
Silicon	0.02%
Copper	0.002%
Nickel	0.003%
Iron	0.003%
Lead	0.02%

Seven of these samples were checked by wet chemical methods for the three major elements. The average deviations were:

Aluminum	0.15%
Zinc	0.17%
Manganese	0.02%

These deviations are of a similar order to those obtained in comparison of the direct reading with the photographic spectrographic methods.

In use with production samples, it has been found possible to make determinations of the eight elements sought during a sparking time of 4 min. Use of a motor to drive the movable tube will permit more time at each position, and so increase the accuracy of the determination, without increasing sparking time per sample. One technician can at present make 80 determinations per hr., while, with two men, the samples can be analyzed at the rate of 100 determinations per hr.

An ingenious method of preparing the alloy samples for sparking has resulted in reducing the time needed to bring the samples to the instrument. Molten metal is drawn into a Pyrex glass tube by means of a suction gun and upon almost instantaneous cooling, the glass is broken away. A rod of metal of correct size for sparking is thus obtained directly from the molten metal in the heat.

This view shows the back of a spectrograph with housing for the reference tube.

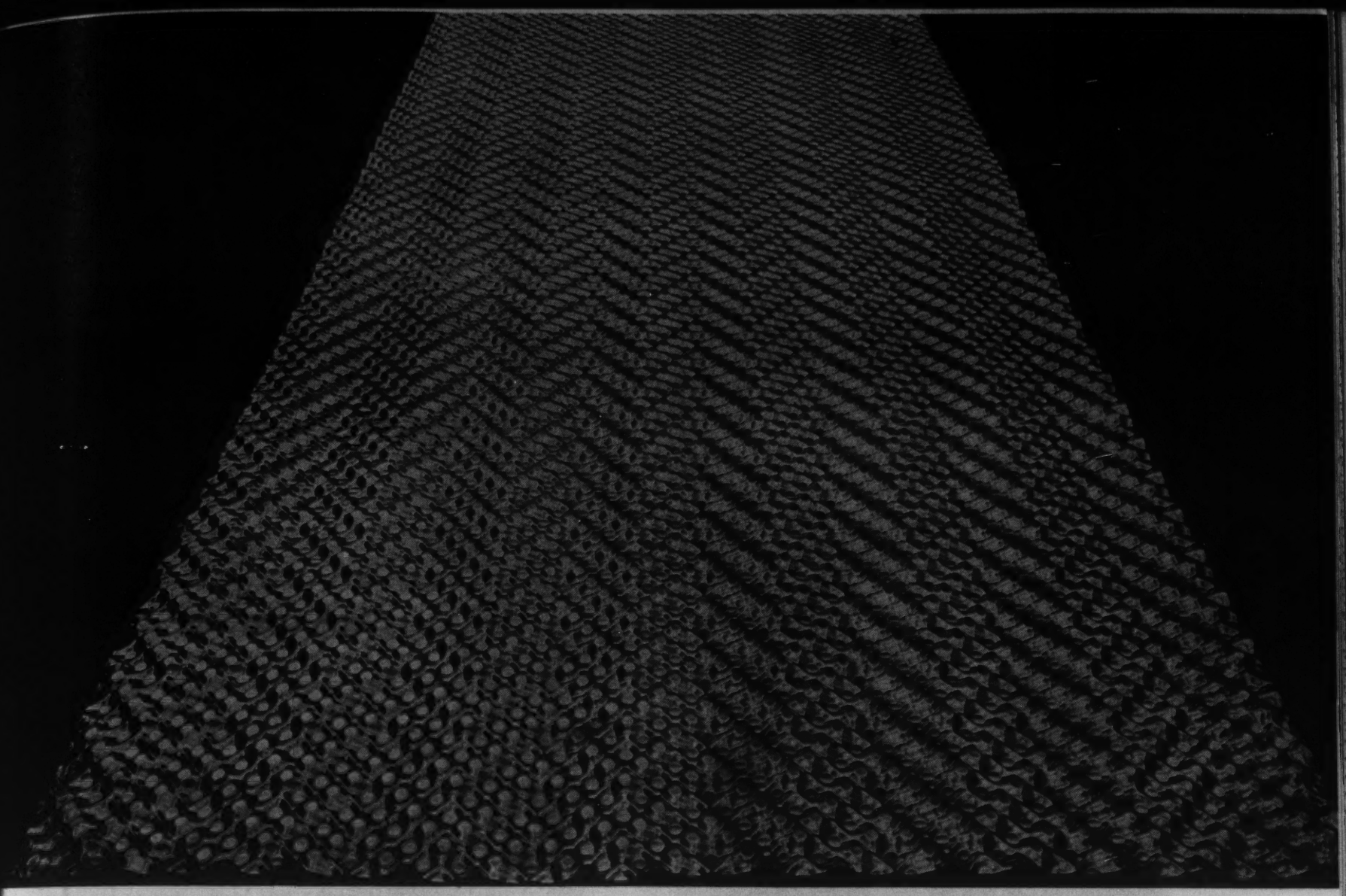


Fig. 1—Here is a large sheet of Rigidized metal, showing one of the pattern types available.

Rigidized Metal—A Modern Material

by D. E. OLSHEVSKY, Ph.D., *Consulting Engineer, Rigid-Tex Corporation*

Design-strengthened in such a way as to increase strength and rigidity in all directions, Rigidized metal has the added advantage of attractiveness.

ONE OF THE MOST VERSATILE engineering materials brought out in recent years is "rigidized metal" in the form of sheet or strip, designed and manufactured by Rigid-Tex Corp., 658 Ohio St., Buffalo 3. It is a "design-strengthened" sheet, with increased strength and rigidity in all directions, by contrast with a corrugated sheet, with strength in but one direction. It has a 2-dimensional pattern of scientifically-shaped alternating high and low areas.

It is highly decorative, highlights giving the effect of two tones, and it may be made into a wide variety of patterns and colors. It shows scratches, mars and soil to a much less extent than plain-surfaced metal. Because of its greater strength, lighter gages can be employed than for plain material for a given application.

Rigid-Tex has 18 standard patterns, but there is no good reason why additional patterns cannot be devised. The makers suggest that it may have its highest usefulness in the more expensive metals, such as stainless steel. They would rather work on No. 20 gage and lighter. The most voluminous application to date has been in seats in buses, such as for backs and kickplates.

Rigidized metals can be in the form of ferrous or non-ferrous metals, including the following: Ordinaty carbon steel, high-strength steel, all grades of stainless steel, coated steel (including galvannealed and lead-

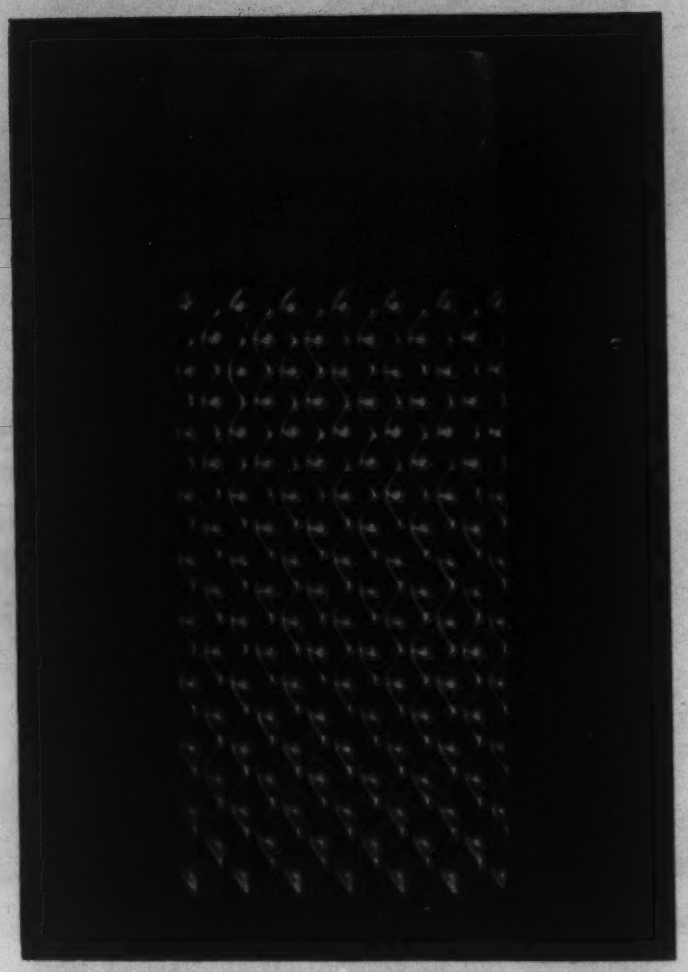


Fig. 2—One of the most popular designs is this which combines attractiveness, strength and rigidity.

coated), aluminized steel, plated steel (with cadmium and chromium); also magnesium, aluminum, copper, brass, bronze, zinc—and in the forms of sheet and strip, coils and cut lengths. It can be furnished plain, or oxidized and highlighted.

Wurlitzer uses it in juke boxes for grilles, having formerly used cloth. The metal does not cut off sound as much as does cloth. (With cloth one needed 75% open area; with metal only 25% is needed.) General Electric employs aluminum anodized and perforated Rigid-Tex on lighting fixtures. It can be used on cold air register grilles; as perforated stainless steel for window shades that slide up into the ceiling of buses.

Consolidated Vultee has used rigidized metal in their XB-36 as leading edges for wings; it can be used for loading ramps for airplanes; it is good for heat exchangers because of its 16% greater area than plain sheets. The National Cash Register Co. employs it for product identification tags. In the novelty field, Chinese match boxes, or cigarette boxes are an outlet. One can use rigidized metal for linings of telephone booths, the rough surface discouraging scribbling by occupants.

The metal has slight resemblance to embossed metal, corrugated metal, or metal weaving, though the makers claim it is more versatile and is essentially stronger. In processing, Rigid-Tex engraved rolls of hardened tool steels are used, with male and female rolls synchronized. A 3-dimensional effect can be attained. In embossing, one uses an engraved roll against a rubber-backed soft roll, but one can't get the high pressure involved in rigidizing.

Background of the Process and Material

Redistribution of metal away from the neutral plane of the rigidized sheet is the basic cause of increased strength and rigidity of the product. Scientific design of the pattern shape, expensive tooling and careful process control are necessary to bring about largest structural gains within the deformation limits of the material as well as within practical possibilities of the process.

Rigidizing, which involves this material redistribution, is done with special equipment designed to effect and guide the flow of plastically deforming metal without internal damages or cracks in the final product. Perfect flatness is being obtained down to the lightest gages.

A number of proprietary processes and design improvements carrying both U. S. and foreign patents are involved, most of them being the result of several years of research and manufacturing experience in producing rigidized metal.

The Rigid-Tex process enables the production of a perfectly even, internally sound, deeply formed sheet at high output rates with consequent economies of manufacture and low end use costs. Both continuous strip and individual sheet processing is possible.

Rigid-Tex Corp. maintains an active research program for development of new and improved patterns, special patterns and assembly methods, pilot production and testing.

Types of Patterns and Their Properties

There have been produced patterns predominantly serving one of the major listed requirements (structural improvement, texture or utility). Fig. 1 shows a representative structural pattern, ACC-41, consisting of a herringbone array of impressions. These are arranged in alternate sequence, that is, one dimple up, and one down. Spacing is ¾ by 1½ in., depth 5/16 in.

One of the most popular textural patterns is 6-WL, Fig. 2. It combines beautiful design with substantial increases in strength and rigidity; it has excellent nonmarring properties. Reflections of light are effectively broken up. The pattern has given good service in objects near windows, such as bus seat backs.

In Fig. 3 we have already seen a dimpled pattern used in combination with a similar rigidized sheet or with a plain sheet in a face-to-face duplex panel. Such a combination provides internal spaces in which fluid can be circulated for heating or freezing purposes. Both applications are in use at the present time.

Listing of the manifold engineering properties of various patterns is beyond the scope of this paper. The reader is referred to a comprehensive Engineering Manual of Rigidized Metal, and to the growing literature on the subject.

In metals subject to work hardening, higher struc-

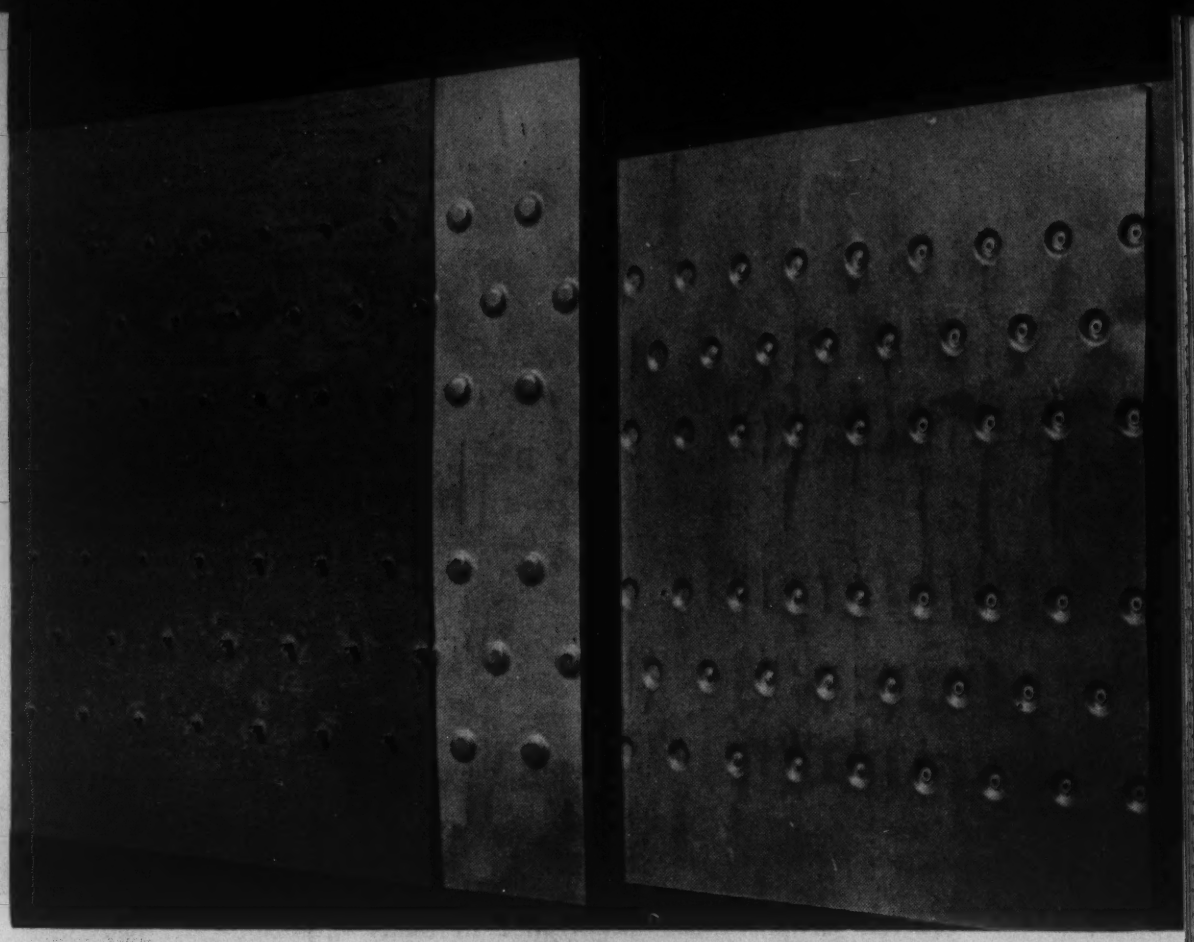


Fig. 3—This dimpled utility pattern is used for heat exchange structures.

turals are obtained not only because of metal redistribution away from the neutral plane, but also because of the improvement in "small region" metallurgical properties of the material. Besides substantial increases in transverse rigidity, buckling and bending strength of the sheet, there is a large increase of impact strength as well.

Results of Physical Tests

EI (Rigidity Values—In. and Lb. Units)			
Material	Plain Cold Rolled Finish	No. 5WL Rigidized	% Increase
SAE 1010 carbon Steel, transverse	47.6	59.6	19.5
Steel, longitudinal	59.0	67.4	14.2
17-7 stainless steel, full hard	14.29	25.88	88.0
24 ST aluminum alloy	7.24	15.07	108.0

Buckling Strength—Psi.			
Material and Finish	Plain Finish	No. 2WL Rigidized	% Increase
SAE 1010 carbon steel, plain (nlt.)	32,700	55,250	70
SAE x 4130 steel (nlt.)	61,300	88,500	44
17-7 stainless steel, full hard (P.L.)	44,000	59,000	35

Impact Strength, Depth of Deformation, In., Stainless Steel			
Gage	Commercial Finish	Rigidized, No. 2WL	% Less Deformation
24	0.218	0.171	21
22	0.187	0.148	20
20	0.191	0.127	33
18	0.118	0.072	39

Tensile Strength, Stainless Steel, Annealed			
Data	Plain, Cold Rolled	Rigizided, No. 2WL	% Increase
Yield	38,950	75,100	92.8
Ultimate	90,600	105,900	16.9
% Elongation in 2 in.	63.5	40.5	—

Strength-Weight Ratio, % (Rigidized vs. Plain)

Greater flexural rigidity 88
Less deformation from impact 39
Higher yield in buckling 35
Higher yield in tension 92

Equivalent Strengths for 1-lb. Stainless Steel (In Terms of Rigidized Metal)

0.52 lb., if stressed in tension
0.74 lb., if stressed in buckling
0.53 lb., if stressed in bending
0.72 lb., if subject to impact

Composite Panels and Structures

By joining face to face various combinations of Rigid-Tex and plain sheets, useful composite of "Sandwich" panels are created. Several efficient combinations have been developed and tested. The following composites are manufactured at present:

Duplex Rigid-Tex, consisting of one plain and one rigidized sheet face-joined together by spotwelding or Cyclewelding. This product is designated by a pair of gage numbers, the rigidized component carrying its capital R mark. The first gage number always designates the face sheet, for instance, .040-.040R, ACC-41 pattern, Fig. 4.

Duplex twin rigidized, more rigid than the straight duplex sandwich, consists of two Rigid-Tex sheets face-joined together. Designation is straightforward, such as .064R-.064R. Standard triplex rigidized sandwich consists of a rigidized metal core sheet sandwiched between two plain sheets. This combination possesses high rigidity and strength properties, Fig. 5. Rigid-Tex stabilized panel consists of a flat sheet with rigidized sheets attached to each side. This arrangement is recommended for beam shear webs as well as in cases where unusually high tensile loads are combined with shear or compression. Standard quadruplex rigidized sandwich of superior

rigidity is obtained by sandwiching a twin rigidized between two flat sheets. Stiffness increases with duplex panels of over 600% can be realized. This represents a weight saving of over 81% in terms of the rigidized sheet weight. In other words, a 181-lb. plate structure will be equivalent to a 100-lb. rigidized duplex panel. To match the performance of a Rigid-Tex triplex panel, two to three times the amount of material would have to be used in form of a solid plate; rigidities of triplex composites run from 8 to 27 times those of equivalent weight plain sheets.

Advantages—Selected Applications

The very substantial improvement in structural properties without added weight is one reason why rigidized metal is valuable to designers and users in general. Of particular importance in many applications is the further quality of enhanced structurals along every aximuth of the sheet, that is, in all directions. It is impossible to cut a strip that is less rigid than the initial flat sheet; while in a corrugated sheet a strip cut in the direction across the corrugations may be several times more flexible than the original flat. These structural improvements are being utilized to permit larger payload of larger loadings in the end use products.

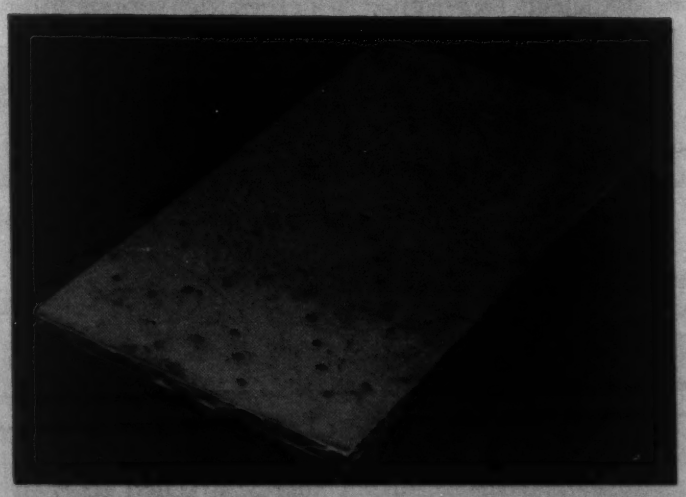
A product using flat sheet metal at present can often be re-designed to rigidized metal derived from a thinner initial sheet gage, effecting a substantial material and weight saving.

The material saving is of prime importance in medium and high price metals, while weight saving has decisive advantages for mobile products. When prime material sheets of substantial cost per ft. are involved, such as stainless steel, rich nickel alloys and even aluminum alloys, the weight saving due to the rigidizing process *alone* often pays for the processing costs.

In certain patterns, a 40% thicker plain sheet would have to be used to obtain the same transverse rigidity. Hence, in cases where this structural quality is the deciding criterion, the break-even point for the use of rigidized metal is established when 40% of the metal price is equal to the cost of the rigidizing process.

The zone of preferred use at present prices and on material saving alone is for aluminum alloys in the medium gages and heavier and for stainless steel in all practically used gages. The estimate refers to structural patterns only, disregards advantages due to weight saving resulting in lower transportation costs or increased payload.

Portability is an important consideration in containers, loading and conveying equipment, air-borne, rail and shipboard equipment and similar items. Parts of railroad cars, buses, airliners, trucks and trailer bodies obtain substantial payload increases due to weight saving from the use of rigidized metal. Such savings often represent direct payload increases and as such are sufficient to more than pay for the rigidizing costs. In certain cases it is even economical to *re-design* for rigid-metal, to scrap the old blueprints, and still show a profit from the deal. Payload and moving considerations extend the field of rigidized metal into low cost materials down to lowest gages of mild and low alloy high strength steels.



Figs. 4 and 5—Fig. 4 (top) shows a duplex panel made by combining one Rigidized and one plain sheet. A triplex panel, Fig. 5 (bottom), faces a Rigidized sheet with two plain sheets.

Advantages Besides Weight Saving

There are other advantages in the process beside structural strength and dead weight saving. The designer's skill that had determined the shape of the first experimental run sheet, has been transferred to the metal. Due to the forming of the production sheet by a continuous, high output process, the user obtains at low cost such design qualities and features as have been incorporated in the original pattern as a result of costly engineering and experimental work. These added advantages can take their origin in the particular texture of the material or carry definite utility features.

The contribution of rigidizing can be classified as:

(1) Structural improvements.
(2) Textural functions.
(3) Utility features.

Fig. 1 is an example of a widely used structural pattern. Texture can carry elements of a beautiful or suggestive and styled design pattern with consequent sales appeal. In modern design, the appearance or eye appeal of the finished product is of major im-

Fig. 6—Here Rigidized metal is used in the oil pan of a Viking marine Diesel engine.

portance with consumer goods and is gaining recognition in the field of machine tools. Well styled industrial equipment creates greater efficiency, easier maintenance, lowered accident rates and induces the operator to take better care of the machine. Due to clear evidence of better sales, industrial designers are aiming at developing products that are not only lighter and stronger, but more attractive as well. This is of importance in objects which we come to see often. It may become a paramount issue in cases where the objects literally live with the user, such as with wall and ceiling interior panels, radio grilles, house and building exteriors, lamp shades and other elements in the interior decoration field. Examples are shown in a collection of miscellaneous decorative applications of perforated rigidized metal in Fig. 2.

But texture is not eye appeal alone. Many Rigid-Tex users have discovered and are utilizing such textural functions as light diffusion and suppression of glare, controlled reflectivity and non-marring properties. Perforated and subsequently rigidized sheets are enjoying at present a particularly enthusiastic reception by industrial designers.

There is here hardly a fixed boundary between strictly textural and utility features; but when a rigidized pattern is engineered and used for heat exchange elements, Fig. 3, it offers benefits of a definitely utilitarian character. In several cases advantages have been gained from automatic layout features of the precision rolled pattern, enabling positioning of fastenings without special jigs or fixtures for the purpose. Sound absorption and non-skid qualities have been designed and incorporated into special utility patterns.

Special patterns and assembly structures have been evolved for applications requiring a high degree of thermal insulation. Properly combined layers of plain and rigidized sheets, when joined face-to-face, result in composite panels of great strength. A plain and a rigidized sheet form a duplex panel, Fig. 4. A triplex sandwich results from two plain sheets face-joined to a rigidized spacer, Fig. 5, in between.

Advantages and Limitations

The pattern of many modern constructions consists of a skeleton representing a system of mutually perpendicular members, covered with plates or panels. In such structures, considerable mutual reinforcement is taking place between the framework and the panel covering. Panels act as diagonals, transmit shear loads. They accept loads perpendicular to their faces and transfer them to the framework. The skeleton reinforces the panel edges, transmits tension and compression. These two mutually reinforcing systems can be observed in such basic construction as trailer bodies, railroad cars, floors and walls of buildings. Presence of supports at the edges of the panels is naturally of prime influence upon the carrying ability of the panel itself while the framework is stabilized against side buckling by the panels.

A rectangular plate made of rigidized metal has increased rigidity in all directions and can efficiently transfer loads to all of its four edges. It also benefits from all edge supports, while a simply corrugated sheet derives little benefit from supports at edges running along the corrugations. Therefore, rigidized construction shows particular advantages in applications to rectangular panels with edge length ratios between 2:1 (through 1:1) and 1:2.

Limitations are experienced sometimes in those structural members where it is not possible to design assembly holes to correspond with the high and low spots in the rigidized metal especially provided for the purpose. Where rectangular panels are used, rigidized metal with flat edges can be specified. Flat pressing of the edges in power brakes can also be performed in many cases. For irregular shapes, such as automobile floors, a solution is obtained in the form of a duplex panel. It consists of a flat sheet fol-

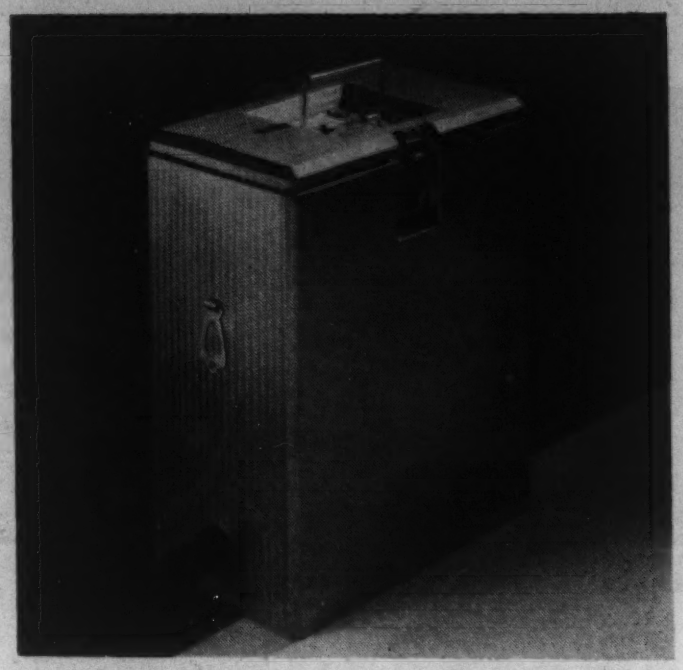


Fig. 7—Rigidized metal adds both strength and attractiveness to this portable canteen for airline and factory use.

lowing the contours of the finished piece and containing all assembly and passage holes and openings. This basic flat piece is strategically reinforced by a deep pattern rigidized sheet, face-joined to the flat by Cyclewelding or similar adhesive forming processes. The sheet is laid out to stay away from edges and fastening holes and to have a simple outline, often with straight line boundaries.

At present the width of the rigidized metal is limited to 36 in. and original sheet thicknesses of from 0.005 to 0.125 in. Production of sheet up to 48 in. is under consideration. There is also a lower limit of ductility at which the metal can be rigidized. This requires processing 24S aluminum alloy sheet in the annealed (0) temper, or immediately after the heat treating quench. More ductile aluminum alloys, such as 52S, are rolled in the "0" or the ¼ hard state. During the rigidizing they develop high structurals. 18:8 stainless steels can be rigidized without difficulty. This is also the case with mild and low alloy high-strength steels. Magnesium alloys are rigidized hot.

Assembly

Cutting-off of rigidized metal is done by shear, or power saw. As the sheets nest into each other, multiple or stack saw cutting can be used. Continuation joints can be lap or butt, the latter with matched backplates. The natural nesting effect of the beads greatly enhances joint strength, simplifies hole layout. Riveting, spot-welding and bolting are all practical since structural patterns are provided with flat contact fields. Cementing (Cyclewelding) of lap joints is very effective due to precision conformity and bead engagement effect. Up to moderate gages the overlaps need not be larger than the space taken up by conventional riveting.

Face-to-face joints create composite panels by combining two or more sheets. Depending upon the shear involved, it is possible to fasten only one out of two or even one out of four contacting flats. This is done by riveting or spotwelding, preferably on multiple head automatics. Cyclewelded panels are particularly useful for triplex and higher order composites.

Applications—By Products

Fig. 6 shows the application of rigidized metal to the construction of marine diesel engine oil pan. Sterling Engine Co., Buffalo, has selected rigidized metal in the 6-WL pattern. It was found possible to substitute a lighter gage rigidized steel for the former plain sheet, with a weight saving of 20%. A similar pattern in stainless steel is being considered for the exterior of several large modern buildings. Decorative appeal was a predominant consideration in the design of an airliner canteen, Fig. 7, and a portable airline ramp. Another unusual pattern is used in form of 1⅞-in. wide stainless strip in the manufacture of a functional part of a postwar photographic camera. It carries a number of utility features, which have been discovered and cleverly utilized by a nationally known manufacturer.

When a previously perforated metal is rigidized, the result is a lace-like sheet with both eye appeal and sound-damping characteristics. Its beauty and utility have led several manufacturers to adapt it for portable and car radio grilles. Transmission of highly pitched noise is decreased and the decorative effect is quite pleasing. In another instance the front panel of a 1947 passenger car uses rigidized perforated sheet back of the vertically striped guard of the grille.

The Future

Since the appearance of rigidized metal in the postwar market, it has been accepted with enthusiasm by those manufacturers who could see immediate applications and carefully considered by those seeing eventual usefulness.

The rate of its use is definitely on the increase and it can be predicted that a period of gradual penetration into specification lists and new designs will be followed by an accelerated rate of use. Several redesigns of established products in rigidized metal are under way, and expansion of this activity can be anticipated at an early date. It offers new advantages and opportunities to designers and manufacturers without radical departures into entirely new domains of materials. The future field of usefulness should extend into most products where rectangular, edge-supported panels constitute a construction element. Because of susceptibility to simple and double curvature bending, even in duplex sheet form, ridigized metal will enter the domain of curved panels. A great field of use in architectural elements is now being developed, both in the exterior and interior field. Far-reaching possibilities are being uncovered for this modern material in the domain of appliances of various kinds.

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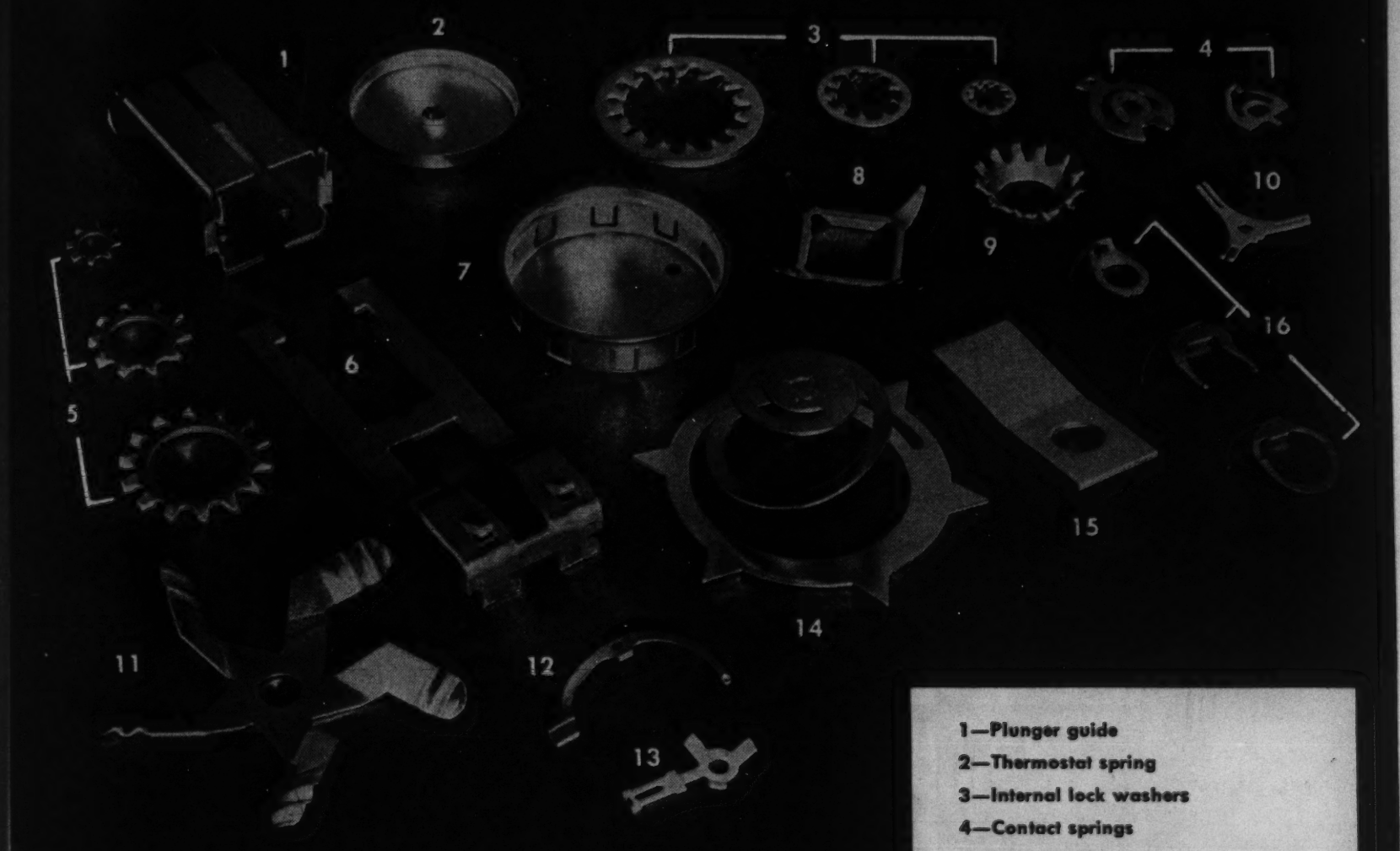

1—Plunger guide
2—Thermostat spring
3—Internal lock washers
4—Contact springs
5—External lock washers
6—Operating lever
7—Cap with integral springs in side
8—Retaining spring
9—Countersunk external lock washer
10—Pressure spring for capacitor
11—Five-contact spring
12—Contact spring for radio part
13—Pressure spring and terminal
14—Involute spring
15—Contact point for solenoid
16—Contact springs
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MATERIALS & METHODS MANUAL

23

This is another in a series of Manuals on engineering materials and processing methods, published at periodic intervals as special sections in Materials & Methods. Each of them is intended to be a compressed handbook on its particular subject and to be packed with useful reference data on the characteristics of certain materials or metal forms or with essential principles, best procedures and operating data for performing specific metalworking processes.

Weldments

by Edwin Laird Cady

Weldments—assemblies or subassemblies made by welding—are being more widely used every day, but there still remain many more instances where such metal forms can be used wisely and economically. Presented in this manual are the many considerations which must be taken into account when weldments are to be used. Also included here are several interesting examples of the intelligent application of weldments.

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Materials & Methods, February 1947

(Published since 1929 as Metals and Alloys)

One of the newer welding methods involves use of inert-gas shielded arcs. (Courtesy: The Linde Air Products Co.)

Introduction

Any discussion of weldments should begin with explanations of how such terms as "welding", "weldment" and "weldability" will be used. This is because an astonishing divergence of opinion is found among technical men as to what these terms mean.

According to one school of thought, any process which joins solid metal bodies with a bond which is at least as strong as the parent metal or metals, is welding. However, with some metals and alloys adhesives can accomplish this, and glueing is not welding.

At the opposite extreme, several men take the position that if actual recrystallization does not take place across the weld zone then the process is not to be considered welding. Such recrystallization sometimes can be accomplished by the use of heavy pressures in welding or by heat treatments which follow welding, so that ordinary etch and microscope inspection techniques are unable to detect any difference between the weld zone and the surrounding parent metal. But this leaves many of the most widely used welding techniques in a limbo in which they would not even have a name. The coining of a special name to describe welding techniques which are so complete that they result in cross-crystallization of the parent metal or metals, does deserve the attention of the welding fraternity but will not be attempted here.

A third idea is that welding is a matter of the completeness of bonding. Every engineer is familiar with the fact that bonding begins in the realm of the intimacy of association which is obtained by wringing the faces of two gage blocks together, goes on through the bond intimacies achieved by plating processes, by powder metallurgy sintering, by soldering and by brazing, and reaches its highest point in the better welding processes. Through this reasoning some plating processes would be more nearly in the welding category than some operations which are generally accepted as being welding.

The whole question sometimes is dodged very neatly by assuming that welding is any metal-to-metal bonding process which is operated at "welding temperatures". Thus, when a metal other than the parent metals is used, as for example a welding rod and the resultant deposit of weld metal, if the operation is carried on at temperatures ordinary for brazing it is called a form of hard soldering or of brazing, and if at higher temperatures it is called welding. Some welding operations, especially the compression welding ones, are being performed at temperatures well below the upper limits of the "brazing range". Everyone is familiar with the fact that some bearing alloys sometimes will form true welds with shafts at temperatures which show no signs of

having been up in the "welding range". In view of some of the pressure phenomena which are being observed by experimenters in supersonics, true "cold welding" as a commercial process may be closer than it is generally thought to be. The temperature at which a process is performed does not seem to be a true criterion of whether or not that process is a welding one.

The term "weldments" is a similar case. To one weldery any fabricated part in the assembling of which welding takes any part is a weldment. To another the assembling of two or more parts or structures by welding produces a weldment, but if the ends of a single part are welded together to make a "one weld" welded ring then this is not a weldment but is a welded ring. To a third, any assembly in which arc welding is used is a weldment, but the products of electrical resistance welding are not weldments although the shop has no other name for them.

On one point the authorities agree. When welding is used to correct faulty castings and make them useful as castings or when welding is used for any repairing rather than fabricating, the product is a repair, not a weldment.

Middle ground suitable for this manual was found by taking general averages of all the opinions which were expressed in interviews.

Welding—When solid metal is caused to so completely unite with solid metal that actual local consolidation rather than mere surface bonding takes place, the uniting process is called welding.

Weldment—When the purpose of welding is to effect an assembly or subassembly rather than to make a repair or correction, the resulting assembly or subassembly is a weldment.

Weld Metal—When, during the uniting process, metal of a different alloy than the original solid metal or metals is deposited at the area of local consolidation, or metal of the same analysis or analyses but of metallurgical structure markedly different from the original solid metal or metals is caused to exist in that area, that different alloy or metallurgical structure is called weld metal.

Weld Zone—The areas of the original metal or metals which are immediately adjacent to the weld, which contain any weld metal, and which otherwise are materially changed by the welding process, constitute the weld zone.

Cross Crystallized Weld—When welding techniques have been such, or heat treatments subsequent to welding have been so applied that no weld zone can be found by the ordinary use of etches and photomicrographs, a cross crystallized weld has been obtained.

Parent or Base Metal—The solid metal or metals to be united sometimes are called "parent metals" and sometimes "the base metals". To avoid confusion with the expression "base and noble metals", the term "parent metals" is preferred for this manual.

Weldability—"Weldability" is one of those terms which have so many connotations that they are more the bases of philosophies than engineering expressions.

In one sense, weldability is an outright measure of the suitability of a metal or alloy for welding. It then means relative ability to be welded, with resultant welds of any desired quality from the crudest of solidification to complete cross crystallization accomplished without benefit of subsequent heat treatment. This can be accomplished with any welding equipment from the crudest of field welding tools to the most highly organized production line equipment, by any widely practiced welding process, by any labor and supervision which can handle welding tools at all, into any weldment designs in which the parent metals contact or come close enough to contacting to make welding possible, without reference to whether the parent metals are in rod or sheet or any other form or to whether sections of unequal thickness are to be welded or the resultant weldment is to be accurate or inaccurate. Weldability in this sense does not extend to different metallurgical forms of the same alloy, as for example, to include cast steel and rolled steel of the same analysis within one category of weldability.

In another sense weldability means ability to be fabricated into weldments with strengths and other properties and at ultimate costs suitable for the purposes of the weldments. Here weldability becomes a test of the weldment designer, the weldment buyer, the end product designer, and of the weldery and other production shop equipment, management and man power.

Weld Efficiency

Weld efficiency, for example, often is grossly over-specified by the weldment designer or buyer, with the result that the weldment costs more than it needs to, or that undue problems of warpage and other accuracies are set up, or even that a highly desirable alloy is pronounced "not weldable at suitable cost into a weldment of this design".

Weld efficiency, as the term is generally used by those interviewed for this manual, means the ratio of the strength (usually tensile strength) of the weld zone to that of an equal section of the parent metal. The term is convenient in that such strength can be measured either by direct testing of the weldment itself or by testing a suitable welded test bar and can be expressed in percentages. Thus, there can be 100% efficient welds, or more than 100% efficient, or 75% efficient, and so on.

It should be obvious to any product designer that no weld needs to be 100% or more efficient unless at least one of the parent metal sections united by that weld is to be stressed to 100% of its strength minus suitable factors of safety. But it is much easier to write "100% efficient" on a drawing than to figure out the actual efficiency that a weld needs.

Over-specifying of weld efficiencies can mean undue costs of machining or forming in preparation for welding; fitting up; positioners and other tools; welding rods or other sources of weld metal; stress relieving; inspecting, and machining, finishing or any other operation performed subsequent to welding. It can require the pouring of too much heat into the weld area with consequent residual stresses which produce an end product of lower strength than could be had with a weld of less efficiency. It can sacrifice the benefits of low-cost forming of metal shapes by demanding shapes which contribute less to the value of the weldment but with which 100% efficient welds are easier to obtain. It can demand that highly complex high cost welding equipment be used when a weld of adequate efficiency would permit the use of simple and low cost equipment. It can require that a higher cost welding process be substituted for an adequate lower cost one. It can mean the use of the most highly skilled, highest paid operators and supervisors instead of ordinary ones.

The weldery manager who meets this "100% efficient" problem can comfort himself with the fact that not so long ago grinding room supervisors were receiving drawings marked "plus nothing minus nothing" and theoretically were not even allowed the millionth of an inch tolerances which apply to the finest gage blocks, and that right now every other metal fabricating process is bedeviled by the same general problem.

Weld Quality

"Weld Quality", as the term is generally used, includes such factors as general appearance, porosity, and cross crystallization. Thus, weld quality has no necessary relationship to weld efficiency. But like weld efficiency, if overspecified it can cause a highly desirable alloy to be rejected as "not adequately weldable for this weldment", and it can reduce the values while increasing the costs of weldments.

If the general appearance of a weld were a good criterion of weld efficiency, then the X-ray inspection of welds, Magnaflux testing, and other methods of testing never would have come into use with weldments. Appearance, then, is to a large extent necessary only for its own sake. Weldments often can be so redesigned, or the end products of which they are members so redesigned or finished, that the higher costs of beautiful general appearances of welds are avoided.

For weldments made of a great many alloys and intended for a great many purposes, weld porosity has been demonstrated to have no effect whatever upon weld efficiency. It does have an ultimate effect when it affords points of ready attack for corrosive or abrasive agents. By all of the common experimental evidence on stress raisers it ought, in many cases, to actually reduce notch sensitivity in exactly the same way that cast iron reduces it by presenting myriads of extremely small stress raisers. However, when the avoidance of porosity is highly important it usually can be avoided.

Engineering Suitability

Since welds which are not cross crystallized often have more than 100% efficiency under tensile, shear, bend and other tests, cross crystallization does not always contribute anything necessary to weld efficiency. But when the weldment is to be subjected to repeated compressive or repeated shock loads which occur at the weld zone, or to repeated abrasive actions at that zone, etc., then cross crystallization can contribute so greatly as to be the difference between the applicability and inapplicability of any weldment to the intended purpose.

Raceways for ball and roller bearings are a case in point. If the loads are heavy and the speeds are high then the rollers, and even more the balls, may be expected to find any tiniest area of their paths which is metallurgically different from the rest and to do damage either to themselves or to that area or to some other area in the vicinity of that one. Cross crystallization can make all areas metallurgically alike and thus can produce weldments which are suitable for anti-friction bearing races.

Similar cases can be found among cam rollers, other rollers, cams, wheel rims, crane hooks and grabs, highly stressed high-speed gears, highly loaded tracks, ways, and gibs. In many of these, welds which are not cross crystallized and which even contain large amounts of weld metal can be so placed that they are subject only to the stresses which they can stand and not to the shock and abrasive stresses. Example: placing the welds of a ring gear blank in such positions that they always will be at the roots of the teeth where bending stresses are least and abrasive wear does not occur.

Cross crystallization has been successful with 52100 and other high carbon, high chromium steels. In this it is extremely important. The higher the carbon, and especially the higher the carbon in an alloy which contains high chromium, the greater the difficulty of obtaining high efficiency, high quality welds. In short, they lower the weldability. In showing a way to overcome this, the fairly new art of cross crystallization opens hundreds of new fields to weldments.

Cross crystallization does not seem to have been tried for a great many other alloys. Its ultimate possibilities are unknown. It may prove highly important in weldments in which the grain direction of steel is carefully directed into the path in which it is desired to conduct electricity, as in the weldment frames of some motors and generators, since the cross crystallized weld can provide more uniform conductance throughout the weldment. It may help where any difference in thermal conductance at the weld can cause a highly accurate weldment to go out of round or otherwise out of true contour, and in chemical equipment in which any changed metallurgical area in a weldment can be a point of corrosive attack. For these and other purposes cross crystallized weldments of the mildest of steels may be made.

Weld quality can be so controlled that the weld zone, even though it may contain large amounts of weld metal, will be of such elasticity, plasticity, stiffness, etc., that it will deform at exactly the same rate as the parent metal, or within close limits, at predetermined greater or lesser rates. By taking advantage of this, two or more pieces of parent metal may be welded together and the resultant weldment be spun, stamped, drawn, forged or machined into a finished part or product.

This appears to be one of the qualities of weldments of which the least advantage is taken. All too often welding is thought of only as a final or assembly operation.

Lukenweld welds large plates together before spinning them. One of the large automobile companies cuts up its larger pieces of sheet steel scrap into matching or mating pieces, seam welds them into useful sizes of sheets, stamps and draws the sheets into mud guards and other parts, thereby easing its steel procurement problem. A screw machine products shop is having nonrollable grades of alloy bar stock precision cast into the 18 in. lengths which this process can deliver, butt welds the short bars into long bars, and then fabricates the bars in its automatic screw machines. By the same process the "scrap ends" of high cost alloy bars, those last bits which are too short to be grasped by the chucks, are butt welded into long and machinable bars. The butt welding of coils of strip steel which are to be fed continuously through automatic processes, the automatic seam welding of pipes and tubes which later are to be machined or bent or otherwise fabricated, are old arts.

A welding positioner aids in the fabrication of this large engine frame assembly. (Courtesy: S. Morgan Smith Co.)

Nevertheless, examples of taking such advantage of the extreme controllability of weld qualities are amazingly rare. Only a handful of examples of hot or cold forging after welding were seen, although this is an excellent method for proof testing the efficiency of a weld, for obtaining high alloy and other high-cost-material forgings with the lowest expenditures for materials and the least scrap loss, for forging heat sensitive alloys with the fewest reheats, and for promoting cross crystallization of welds. No example of cold extruding after welding was found. Instances of case hardening after welding were reported but no actual examples could be run down.

Some of the very best welderies, indeed, looked upon any post-weld fabricating which would include fabricating of the weld zone much as old fashioned "blue bloods" regarded the Ellis Island immigrants; something alien to their art, to be held within a limited sphere of activity. Yet by control of weld quality the weld zone can at will be made to conform to the physicals of the parent metals, or to be a zone of different elasticity, stiffness, hardness, etc., and thus a weld zone can be made a substitute for costly machining and forming and other operations intended to obtain these same properties within a narrow area, and this fact alone is enough to assure a brilliant future to pre-fabrication welding.

The somewhat close control of weld quality can reduce the costs of weldments by requiring better supervision, performance and tooling up at the welding operation and by leading to better weldment design. In many cases quality control costs money. The exact factors and specifications of weld quality, then, should be laid down in accordance with the end use of the weldment and with all of the fabricating steps and the selections of materials affected.

Stress Relieving

One of the problems of weldment design and production is the relieving of residual stresses. Welding, as ordinarily done, does pour large amounts of heat into small areas of parent metal and does thereby result in residual stresses. Residual or "locked up" welding stresses are much like casting stresses in that they occur most damagingly at areas from which heat cannot readily escape. "Hot spots" or heated areas which have large volumes of parent metal and relatively low surface areas from which the heat can escape, and junctures of thin sections with thick ones, are examples. As with castings, the residual stresses of weldments seldom are as damaging as theory would make them, and often are blamed for troubles which they do not cause.

The unanimous opinion of the authorities interviewed for this manual is that the best stress-relieving method is to so design weldments and work out welding sequences and handle pre-weld and post-weld fabricating procedures that no stress relieving is necessary. This method is even being followed by welding engineers who in former years issued scientific papers showing that damaging welding stresses are almost impossible to escape and must be relieved.

To avoid the need for stress relieving, several rules are recommended for weldment design. Among them:

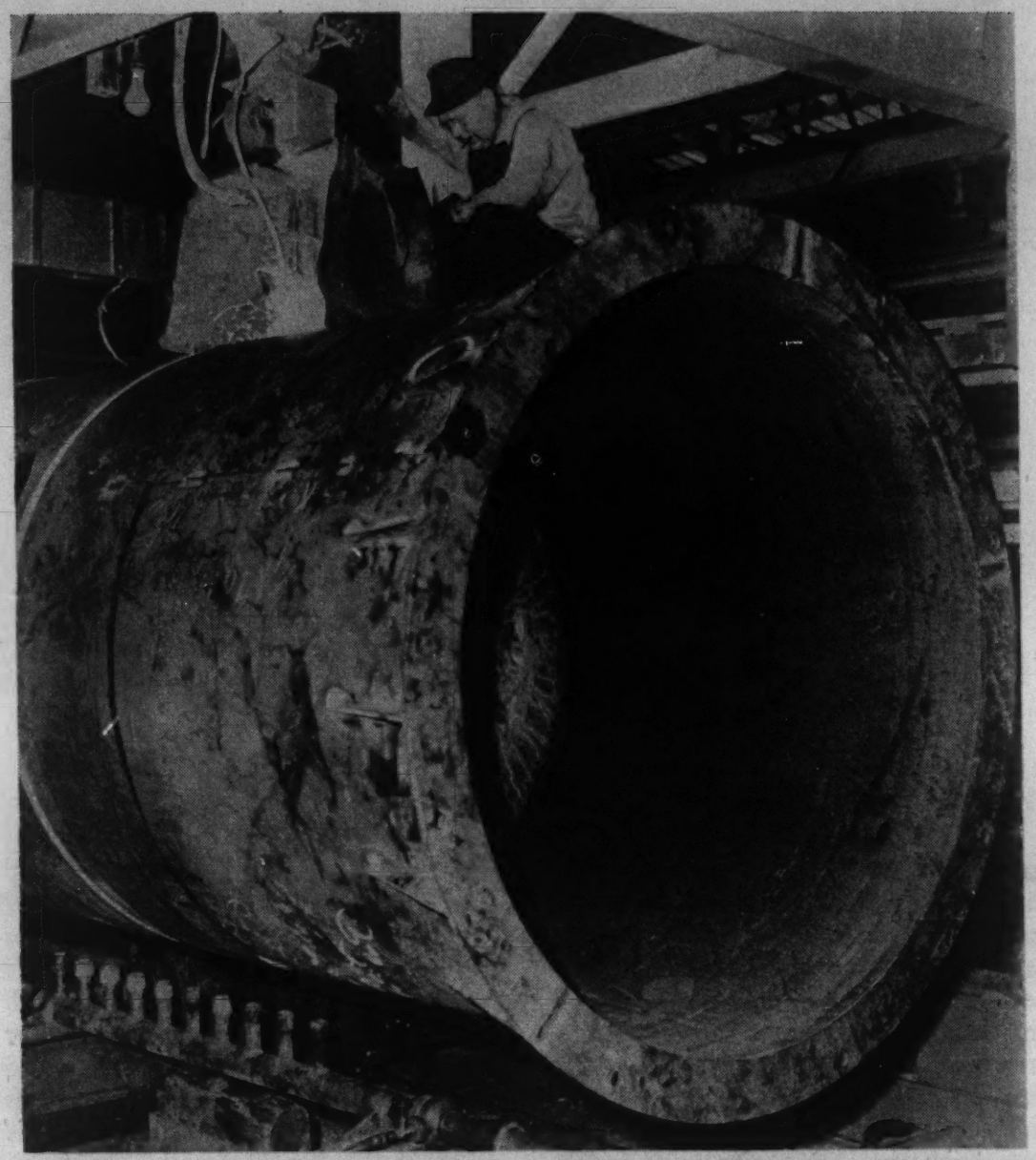
(1) Do not insist upon a weld of higher efficiency, nor upon welding a greater proportion of the mating or contact areas of the weldment members, than necessary for actual stresses to be carried or actual need for closing or sealing. The larger the areas of welding the greater the input of heat and the more the troubles of residual stresses.

(2) Do not "go over-board" for weight reduction unless designing air craft or some other structure in which light weight is vital. A slightly heavier parent metal member which, relative to its own strength, can carry all of its stresses with a 75% efficient weld, is much better and usually is much cheaper than a lighter one which needs a weld zone of 100% of its own strength to carry the load. And the heavier member with the 75% efficient weld will, all other factors being equal, usually have a much greater excess of strength over the residual stresses.

(3) Design to use structural shapes which have large amounts of surface area in proportion to their bulks and weights and which depend upon curved or other non-flat surfaces for their strengths and stiffnesses. Tubes, half rounds and channels are examples. Such shapes usually can be welded with less total heat inputs in ratio to their strengths, and almost always can get rid of the welding heat to better advantage.

(4) Design to use spacer plates and other strategems which avoid the making of several welds within one small area. Do not design a "hot spot trouble" into the weldment.

(5) Avoid designs which result in several members being under stresses which affect each other. In theory the stresses of several members can be made



Automatic arc welding equipment, with a preheating device, is used to fabricate a huge high-pressure tank. (Courtesy: General Electric Co.)

to cancel each other. In actual practice, when more than two integral members are bearing residual stresses, engineers find it almost impossible to estimate the magnitudes of those stresses. The trouble comes from the fact that in making two weldments of the same design the heat input to one may vary widely from that of the other, and each heat input may vary from what the engineering calculations said it would be. Two or more members which impose straight tensile or compression residual stresses upon each other are not too bad. But when one which is in tensile residual stress has imposed upon it by the others shear stresses more or less compounded by leverages a stress relieving operation usually is indicated, especially if the resulting weldment is to carry dynamic rather than static loads.

(6) When residual stresses of weldment members tend to complicate each other and several weldments of the same design are to be made, design for an automatically controlled welding process rather than for one which depends upon the personal judgment of the welder and his supervisor.

(7) Design so high inputs of heat can be used to complete the welding quickly. The total BTUs of heat which the parent metals will pick up, and hence the total amounts of residual stresses, are more a matter of the length of time of exposure to the heat than the amount of heat to which they are exposed.

(8) Design so the welds are in fair areas so the welders or the welding equipment can get at them for a sensible welding sequence. By making part of one weld, then part of another, then going back to the first, etc., the total heating up of the parent metal and hence the total of residual stresses can be kept down.

(9) Design so that several weld zones will carry the loads on a weldment member rather than one big weld zone, as is done with multiple spot welding, projection welding, skip welding, and the like. This reduces the residual stresses and also avoids localizing them.

(10) There are tricks such as prestressing the weldment members, cutting plate edges to slight curvatures so the welding process will pull them straight, and otherwise "using up the residual stresses by making them work". Avoid these unless a skilled welding engineer has certified them for the weldment in question.

(11) Always consult the weldery while the weldment design still is in the rough sketch, schematic stage. This is the most important rule.

In spite of these and other resources, many weldments will have to be stress relieved. And many designers and welderies stress relieve nearly every weldment in response to a "safety principle" which almost amounts to a superstition. Where stress relieving must be done there are other rules to follow. Among them:

(12) Design with a definite stress relieving procedure in mind. The most common ones are sub-critical anneal, full anneal, peening, vibrating, stretching or deforming the weldment beyond its elastic limit or doing other cold work on it, post-weld hot forging, local annealing, heat treatments which harden or temper but incidentally stress relieve.

(13) If either sub-critical or full anneal is to be used, design so the weldment can be properly supported during the heating and cooling processes and undue deformation can be avoided. Support can be: (a) the weldment members retaining enough strength at the annealing temperature so they will not bend or collapse; (b) blocking up within the furnace so the blocks support the members; or, (c) annealing in a fixture which maintains member dimensions and alignments while it supports.

The most common method is a sub-critical anneal which does not change the grain structure of the parent metal as a full anneal would. Here, for example, a steel weldment which at room temperature has a tensile strength of 90,000 psi. may be heated until the remaining strength at the anneal tem-

perature is 6,000 psi. If cooled slowly and carefully enough so the cooling does not result in further residual stresses, it then can have no residual stress of magnitude greater than the order of 6,000 psi. And at room temperature it may be safely calculated to have a tensile of at least the order of 84,000 psi. with other strengths to match. But while it is at its highest temperature its members cannot support their own weight beyond the order of that 6,000 psi. strength, and in most cases if unsupported they will bend, twist, or otherwise deform.

If the weldment is to be blocked up for support it must be so designed that its weakest and its critical areas are accessible for the supporting blocks without too high cost for making special blocks and fixtures and for assembling the support structure beneath the weldment areas.

Fixture annealing of weldments is a fairly new art. It requires careful design and production of the fixture, careful control of the furnace. New technical papers are expected to be issued on it in the near future. Several authorities said that if properly practiced, fixture annealing can result in highly satisfactory sub-critical anneal stress relieving, free of any significant distortion or dimensional changes of the weldment. Strain movements which ordinarily are associated with the relief of stresses all take place within or between the crystals of the parent and the weld metals.

(14) If intending to stress relieve by peening or vibrating, design the weldment so the weld zones will be fully accessible to the necessary tools. Peening is a well developed technique, vibration is not so well known. Vibrating at supersonic frequencies for purposes of stress relieving may be one of the important new techniques of the future.

(15) Welding stress reliefs which are incident to post-weld fabrication operations, such as stretching, hot forging, and hardening of the weldment, are to be preferred. Usually they can act as simultaneous stress reliefs and tests of the efficiency of the weld.

(16) Local annealing of the weld zone and the adjacent parent metals may immediately follow the welding operation by applying heat to cause the weld zone to cool slowly, or can be a separate operation. In electrical resistance, flash or spot welding it can be done with a special annealing current which follows the welding one. In gas welding the flames can be made to control the rate of cooling. If planning for such local annealing, the production equipment must be ample in capacity so the weldment can be allowed to dwell in the welding fixtures while the slow cooling is done, or the equipment must be amplified so there are secondary stations to which the weldment can be passed for local annealing immediately after completion of the welding operation. Local reheating after the weld has cooled sometimes is more practical, and with some parent metals and some types of welds can be a test of weld efficiency and quality, but this seldom is a preferred method for the repetitive production of duplicate weldments.

The use of tubular and other high-strength-for-weight members can do much to reduce stress relieving problems.

The entire subject of stress relieving for weldments and other parts and assemblies is under intensive research right now and important announcements concerning it can be expected.

Weld Testing

Like weld efficiency and weld quality, weld testing has been grossly over-specified with the result that weldment costs have been much higher and weldment performance values in end products much lower than they need to be. Modern weldery procedures can be trusted to a far greater extent than many weldment designers and buyers believe. Where testing seems to be wise there are rules which can reduce its costs:

(1) Design and specify to somewhat higher weld efficiency and quality, somewhat more thorough stress relieving than is absolutely necessary, and with these margins of safety eliminate the testing.

(2) Prefer tests which are automatically made during the performance of post-weld secondary operations on the weldment. Examples are stretching or forming or other cold deforming operations which exceed the elastic limits of the parent metals and thus cause the weld zones to prove whether or not they can perform satisfactorily under those forces, and electropolishing which will separate bad welds in stainless steels.

(3) Prefer nondestructive tests such as X-ray, Magnaflux and supersonic, but design to get the weld zones out into fair territory where these tests can be applied.

(4) Unless the weldments are small and inexpensive, use test bars and test specimens rather than destructively testing whole weldments. Do not instruct the weldery to supply test specimens having weld efficiencies of 100% or over if the actual welds are to be only 80% or less.

Weldment Economics

The cost and value of a weldment can be judged only from a viewpoint of the end product of which it is to be a part or which it is to become.

The cost of a weldment is the sum of all the costs of its production, and of these the actual welding operations usually are but a small part. Among the costs are pre-weld and post-weld machining, forming, forging, finishing; welding costs of fitting up, positioning, welding, inspecting, stress relieving, flash removal.

Usually more money is to be saved and more weldment value created by taking every possible advantage of pre-weld and post-weld metal forming operations than by using any of the tricks of welding.

The specifying of parent metals too light in weight or too thin in sections are common mistakes which lead to high weldment costs and reduced weldment values. Similar errors are the over-specifying of weld efficiencies, values and inspection requirements.

No newly designed weldment intended to be made in large quantities should be considered as in its final design stages until every welding process has been considered for it or for its weldment subassemblies. Different welding processes are at their best for different modifications of weldment designs. There are surprising and costly mistakes of this kind.

No alloy and no contours of weldment members desirable for a weldment should be considered "unweldable" before every welding process and every weldery which has high control of its processes has been considered, or before every resource in the use of other fabricating equipment to reduce the problems of welding has been explored.

Every metal part having junctured members which could be integrated should be studied for the employment of weldments. Thousands of highly profitable uses of weldments have not even so much as been pencil sketched by product designers.

Planning and Designing Weldments

The development of a weldment can be a lengthy process. Thus, the working out of a railway car journal box which formerly was made of a single casting and now consists of four forgings welded together, took nine months of designing, trying and road testing. The forgings-weldment box will be lighter, stronger, and capable of taking sleeve bearings or ball or roller bearings interchangeably, and will be much stronger and durable—common benefits of weldments.

Methods for working out weldments as presented here are a composite of those used by several welderies having high professional reputations and of several buyers and users of weldments.

(1) Determine whether the weldment is to be made on the equipment available in, or readily available to, a single weldery, or the production of the weldment is to be thrown open to various welderies having varied equipments, or new weldery equipment can be bought to make this weldment. Sometimes this decision is obvious. Sometimes it will be changed with every progressive step in the weldment development. These same factors apply to any product to be made by any process.

(2) Break down into functional elements the entire device in which the weldment is to take part. If a weldment base, or frame, or guard, or drip pan, etc., is planned, do not stop with the study of that one device. Surprising opportunities to make functional improvements will be found, even when weldments take no part in them. But the chances to improve by the use of weldments are almost unlimited.

(3) A simple beginning is to break down all elements by their functions into bases and frames, wheels and gears, containers, covers, shafts or rods mostly loaded in compression or tension or shear but dynamically loaded (a revolving shaft becomes a wheel in this study).

(4) If the task is the redesigning of an existing machine and castings were used on the original, call in a "castings engineer" and find out what contours and dimensions and weights of the castings sections were put there for functional reasons and which ones were solutions of foundry problems at probable sacrifices of functioning abilities. Proceed similarly with stampings, forgings and machined elements. Weldments may eliminate some of the sacrifices of functions, may permit functional designs not even considered for other products, but may also cause their own functional sacrifices. If there is any production process which eliminates all problems of functional design, then welding is not it.

(5) Work out as much of every basic weldment design as practical in terms of standard structural shapes, bars, sheets, plates, etc. Do this because it is simple and because the strengths of these shapes are well known and are easily found in various catalogs and hand books.

(6) Calculate all stresses and strains, all needs for stiffness, rigidity, resiliency, etc. Rework the standard shapes design accordingly. Calculate the static stresses first, then the dynamic ones. Static loads usually are much easier to figure.

(7) Estimate the needs for corrosion and abrasion or erosion resistance of the various parts. These ordinarily are matters of surface resistance or surface area resistance only.

(8) By this time the ideas of what to gain by bending, forming, accurate machining, heat treating, selections of materials, etc., will inevitably be well under way. Make a basic rework of the design accordingly. But never get away from the functional conception of every part, subassembly and assembly. Think always in terms of functions and the end design will be more salable, cost less, weigh less, and be quieter, more durable, useful, and easily maintained.

(9) Break down every complex weldment such as a base, frame or gear into weldable subassemblies, these finally to be welded into the main assembly. Plan to do all possible surfacing, surface plate applying, stress relieving, and weld inspecting on the subassemblies. In general, the smaller the weldment the less costly the problems of machining or other pre-weld operations, of fitting up and positioning and other welding operations, and of forming and stress relieving and other post-weld operations.

(10) Remember at this point that good welding begins on the drafting board. The same is true of good machining, casting, and other operations. Avoid designing welds that need too high efficiencies, accuracies, qualities, or too costly or "tricky" inspection methods, or are in positions difficult or costly for welding. Design so that no stress relieving is necessary, or failing this, do not so design that stress relieving will be unduly difficult.

(11) Consider carefully what the welding procedure will be. A welding procedure is a sequence of welding operations, or of welding interspersed with machining and bending and forming and other operations, which will eliminate the most practical amounts of residual stresses and result in a weldment of the highest necessary accuracy and strength and greatest desirability. Such a procedure may need long experience plus painstaking trial and error at the weldery which is to work it out. Three of the best welderies said that it takes about six trials of procedures to find a satisfactory one for a new and complex weldment.

(12) In the final weldment consisting of welded or other subassemblies, provide "through holes" and other facilities so that men and tools can get at the weld areas for welding, weld inspection and finishing operations. High and unnecessary costs can be built up if this is not done.

The problem of what operations should be pre-weld and what post-weld can be the subject of imaginative visualization on the part of the designer.

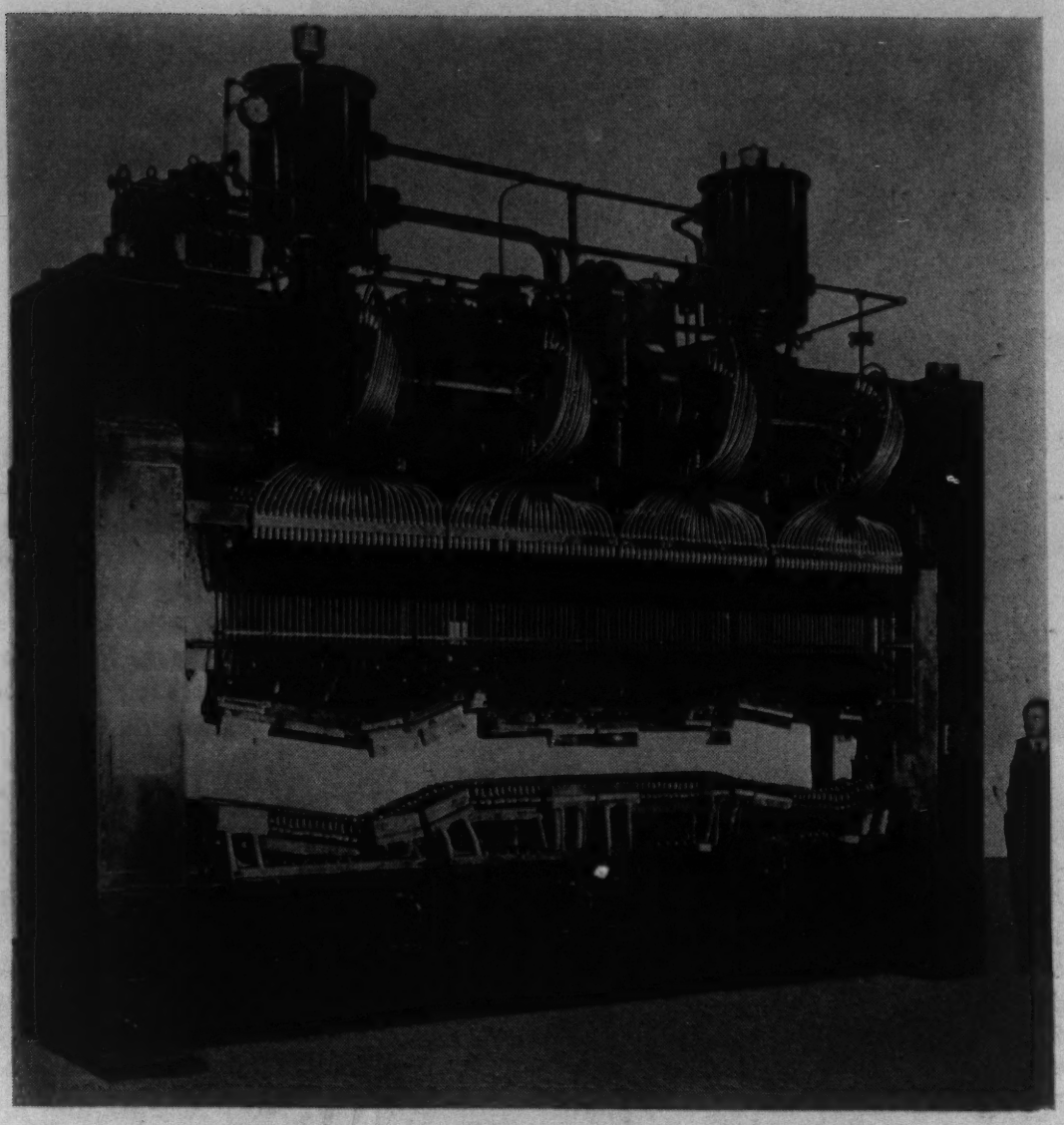
There are no fixed rules that cannot or should not be broken. There only are generalities.

Strength, in general, seems most often to be created in the pre-weld operations. Parts can be bent or formed for strength, then their strengths united by welding. Forming to achieve strength and stiffness almost always is less costly than the welding-on of strength giving braces and other members. But there also are plenty of cases in which the forming should follow the welding and the weld area should be formed in the same operations as the parent metals.

Accuracy, in general, seems to be most easily achieved in post-weld operations. It is true that accurate shapes can be welded to accurate shapes to produce accurate weldments and that much depends upon the shapes, the sizes, the necessary efficiencies and

qualities of the welds, the positions of the welds, and whether or not the strength will be achieved by the use of many small welds as is usual with spot or projection welding or with a few larger welds. Opinions as to what accuracies could be achieved by welding processes alone vary so widely that no averages will be attempted on this subject. All experts agree that accuracy is most easily achieved by such post-weld processes as straightening, machining, grinding, forming, expanding and forging, in which case the accuracy is that of the post-weld and not of the welding process.

Several apocryphal stories were told about a shop which achieved plus or minus 0.002-in. accuracies on weldment machine bases which were more than 14-ft. long. A prominent general magazine even published such a story. Investigation of the weldery which makes those bases produced loud laughter by the weldery engineer, plus demonstration that the bases were first welded, then stress relieved to get the warpage out of them, then cast iron pads were welded to their top surfaces, then the bases were mounted in a planer and the pads planed so the structures mounted on them would be supported with the required accuracy and alignment. A weldery engineer famous for the accuracy with which his shop welds heavy studs said "By care in the weld procedures I used to weld them straight and square for $2.00 each more than ordinary welding cost; I now weld them at ordinary cost and straighten them hydraulically for less than 50 cents each."



This giant welding press is of the type used in the rapid fabrication of automobile frames. (Courtesy: Westinghouse Electric Corp.)

Corrosion and Abrasion Resistance

Weldments can be corrosion or abrasion resistant because of the natures of the parent metals and their matching weld zones, or can be made so by hard surfacing or other surfacing with rod welding, or by welding strips or other shapes to their surfaces, or where the strips or shapes may need to be renewed, by screwing or bolting them to the parent metal and then filling in the counter sinks or covering the heads by rod welding. The abilities of these processes to solve problems never should be overlooked. But the problem of whether to perform these operations before or after completing the main weldments can be solved only by consideration of design factors and of production convenience with surfacing while parts are small preferred.

Machining. Weld zones which will machine with exactly the same characteristics as the parent metal, or with other desired characteristics, can be produced. But weld metal, or in the case of cross crystallized welds any other metal at the weld zone, is costly metal and there is no point in putting it there and then carving it away if design factors can avoid this.

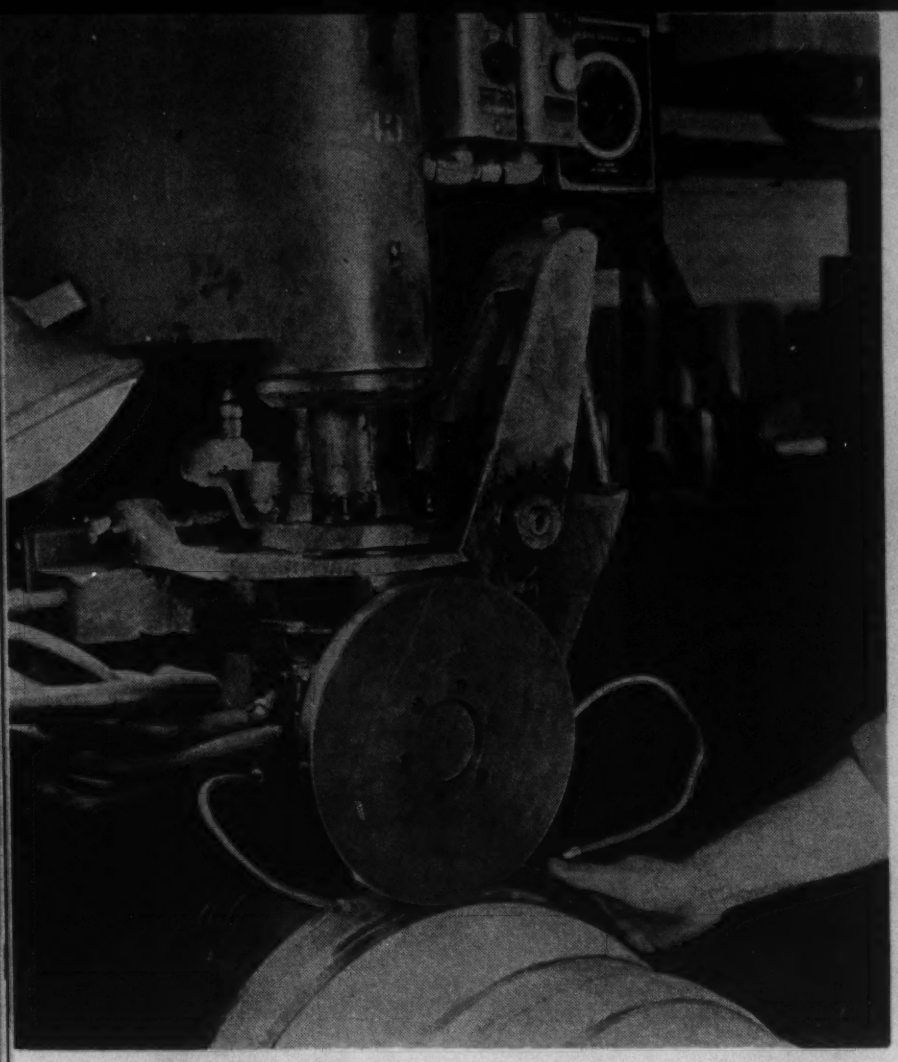
Induction Hardening. Several instances of induction heating for the hardening of local areas of weldments were found. All of them were just getting beyond the experimental stage. They are a comparatively new resource in the functional design of weldments. They are post-weld operations.

Flame Hardening. Flame hardening is an older resource, but would be helpful in a great many instances in which it has not yet been considered. The weld zones usually are so located and the flames so directed that the weld zones are very little affected. But weld zones also can be hardened if specially planned for this.

The importance of designing for correct fabrication procedure, including correct welding procedures, cannot be over emphasized.

In the plant of the S. Morgan Smith Co., weldments more than 20-ft. in dia. at their bases and more than 35-ft. high are so fabricated that after a few correctional operations the run out of any part of the periphery of the base when the weldment (a giant water turbine device) is turned on the centers of its 35-ft. high extension, or the run out at the top of the 35-ft. high extension if the weldment is turned on true mountings at the periphery of its base, in either case is less than that quite often allowed to very small parts which have been machined in lathes.

Such "miracles" of accuracy are pro-



Here a seam welder is producing a circumferential weld to join a large flange to a cone. (Courtesy: General Electric Co.)

duced by careful developing of sequences. The rough plates for the devices to be built are cut to shape, and are formed to true contours. Castings and forgings are machined as needed. Then small subassembly weldments are made, stress relieved, machined accurately, welded into larger subassemblies which are stress relieved and mounted on huge boring mills to be machined accurately before being welded into still larger subassemblies. The company is one of the prime movers in the development of warp-free stress relieving, and of the welding procedures which make this easy to do.

The making of the two booms, one of which travels within and therefore can be extended beyond the other, for the road grading machine at the Warner & Swasey plant is another example. The outer or female member is 16-ft. long and the inner or male member can extend 12-ft. beyond it. Both are triangular in sectional shape, made of tubes and plates.

The 1010-1015 3/16-in. thick steel plate for the side walls is punched for lightening and is flanged at the holes for appearance and stiffness. The tubes, one for each corner of the member being made, are mounted on studs at each end, the studs in turn being mounted on heavy plates which are held by shafts at their centers so the whole mounting becomes a welding fixture which can revolve on its own axis and permit all of the arc welding to be done in the down hand position. The plates then are tack welded to the tubes. A carefully developed welding sequence is followed by which the welder works at one area, then at another, keeping all stresses carefully balanced and never pouring too much heat into one area of one tube at one time. Because the tubes are held against sideways movement all stresses, as the welds cool, must manifest themselves as longitudinal pulls against the tubes can do no harm. Such sideways stressing as the welds—and therefore the plates—may do, will act as stiffening forces for the whole structure and therefore be beneficial. If necessary the plates are finally straightened by spot heating.

Similar procedures are to be found in every weldery, and make use of nearly every welding process. In one railway car shop 30 separate formed metal items are spot welded into three separate subassemblies which in turn are spot welded into the completed weldment. The spot and other welding equipment necessary for this and other tasks on the production scale of this weldery would cost at least $100,000 before tooling up, and the tools probably are worth $50,000 more.

Production Factors for Weldments

A weldery is a shop or a group of machines specifically designed or set up to perform or to assist with welding processes. The weldery can be a job shop doing welding on contract, or a separate factory department complete in itself, or a group of machines which are part of a general production or assembly line and are located within the line.

As a general rule, only a few machines in the weldery do any welding. There are a few instances in which the welding equipment alone is separately housed in a building which is called the weldery. In most cases welding equipment is ganged with machines for flame cutting, cold sawing, cold or hot bending, forming, flash removing, expanding, forming, inspecting, stress relieving, finish grinding, painting or other finishing equipment, and the like, and not one machine or operation out of every five in the weldery does any welding.

Weldery equipment, then, includes all of the pre-weld and post-weld machines and processes necessary for the production of weldments.

Welding machines and equipment exist in at least as many types, varieties, simplicities, complexities and capacities, as do metal cutting tools or any other kinds of metal fabricating equipment.

At one end of the complexity range would be a simple oxyacetylene torch, or manual arc welder, or single spot resistance tack welder. At the other end might be a special spot welder for aluminum. On this machine the electrical discharge must occur at the exact moment that the pressure between the two pieces of parent metal is right. The machine is operated with a two-piece or interrupted section ram. Separating the two sections of the ram is a bellows. As the upper section is brought down against the bellows, the bellows transfers the force to the lower section but also registers the pressure within the bellows on a highly sensitive electrical circuit. The circuit is so arranged that the electrical weld-

ing current discharge is said to occur within one micro second of the reaching of the exactly desired welding pressure between the parent metals.

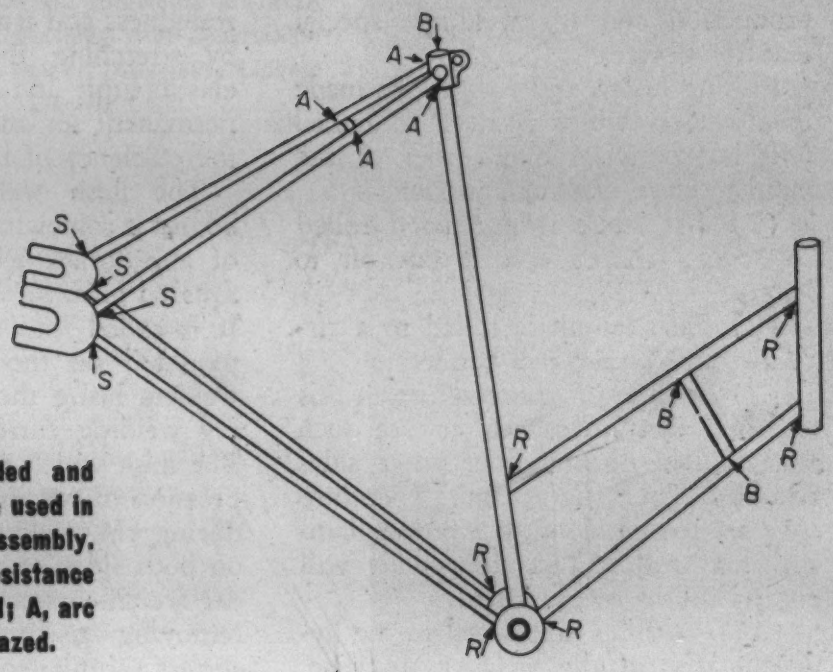
The weldment designer, then, has his choice between designing for production on the weldery equipment immediately at hand in his own weldery or in his favorite jobbing welderies, or of designing his weldment first and later finding out what weldery can make it or what additions to his own weldery will be needed. In this regard he is in the same situation as that of the castings designer in relation to foundries and the machined products designer in relation to machine shops. The choice he should make depends upon the functions to be performed by his weldment, and if the weldment is complex, the contributions of its various elements and contours to its functions.

Several different types of welding operations can be performed in the fabrication of only one asembly. A weldment as simple as a bicycle frame is an example.

This weldment includes seven different resistance welds, for 100% efficiency of the welds; four spot welds, for high speed and low cost; four arc welds, because the operator can readily get at the weld zones which are not readily accessible for resistance or spot welding and the arc welding has proven less costly than brazing; three oxyacetylene brazed joints, selected as a process because the speed with which the operator can get at them makes this process the most economical. Other bicycle frames made in this shop have different weldment patterns.

The resistance welding between the front post and the frame members leading back to the seat post is a somewhat involved operation in that the front post is of a different diameter and thicker gage than the other members and resistance welding is at its best when the parent metals at the weld zone are of exactly equal areas. To overcome this a special production method is followed:

(1) Tubular steel pieces having outside diameters equal to the inside diameters of the frame members, and having inside diameters such that when added to the metal at contoured ends of the frame members a total area equal to the front post area contacted will be presented to the front post, are made in an automatic screw machine.



Fifteen different welded and three brazed joints are used in this bicycle frame assembly. Joints marked R are resistance welded; S, spot welded; A, arc welded; and B, brazed.

(2) The tubular pieces are swaged into the ends of the frame members, the ends of piece and member being flush when swaged.

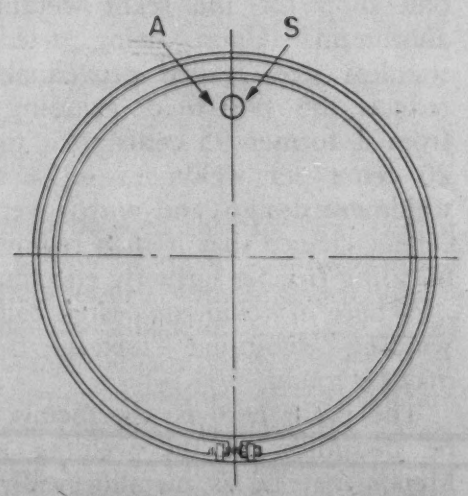
(3) The ends of these assemblies are contour milled to fit the curved surfaces of the front posts. The dimensional accuracy of the milling is to the order of plus or minus 0.002-in. For purposes of close control of the resistance weld, contouring of the milling cutter and the set-up of the frame members has to be such that, when the cutter takes the curved bite out of the end of the frame member to match the curved surface of the front post and takes that bite at the angle with the frame member at which the frame member is to join the front post, if a piece of paper were pushed against that milled surface in such manner as to be cut by all edges of that surface at once the disk and the ring thus cut from the paper would be true circles. The true circle of contact makes for uniformity of distribution of electrical current at the weld zone and therefore for uniform 100% efficient welding.

(4) The welds are made and the flash removed.

All of the weldery equipment necessary for the production line fabricating of bicycle frames in this shop would, if bought new, have an installed cost of over $50,000.

Weldery equipments having installed costs of over $500,000 are not at all uncommon.

Steel barrels as weldments usually include at least five flash welds, three arc welds, two spot welds and one or more oxyacetylene gas welds. The number of each depends upon the type and purpose of the barrel, the openings and reinforcements and other features, and the size of the production run. Flash welds are preferred for their low costs wherever the contours of the pieces to be welded are uniform enough to permit them, and the production runs are large enough to make them economical. Arc welds, at the plant interviewed, are found to be generally more efficient than flash welds and also to be highly economical because of the versatility of arc welding. Spot welds, wherever they are practical, are preferred for low cost. Gas welding is the most versatile process and is used chiefly on small lot



The making of a steel barrel can utilize several different welding methods. Here, for instance, is a ring which is either arc welded or spot welded.

production and for welding "special feature" devices.

Rolling hoops and flanges are made in a weldery which is a self-contained unit but occupies one corner of the main weldery. The operations:

(1) Bar stock is purchased rolled to special shapes and is cut off to length.

(2) Each length is rolled to a circular shape on a 3-roll bender.

(3) Because of strains set up in this shaping, the circles seldom are such that if laid on the floor their sides would lie in a flat plane. Therefore they are passed along to a power hammer and restored so their ends will come close to meeting truly.

(4) The rings are placed in the hydraulic dies of the welding machine. These dies do any slight repositioning of the ends needed to take out any remaining side bend and bring them into true mating alignment, also bring the ends together under welding pressure. The welding current is turned on and the flash welding operation performed.

(5) The ring weldments are taken to a flash removing machine, or the flash is chipped off with an air hammer.

(6) The ring weldments are put on a hydraulic stretching machine which, in stretching them to size, produces true roundness and true side planeness, and by stretching the metal beyond its elastic limit and causing it to take a permanent set, makes a 100% test of the efficiency of the weld.

The flash welding of the barrel bodies is somewhat similar. Sheet steel of appropriate gage is bought in re-squared form for dimensional accuracy. It is rolled into cylindrical form and mounted on the flash welders. The welders bring the edges together, apply welding current, do the welding. The flash which results from the compression of forcing the edges together during the welding, should be equal on both sides of the sheet. The cylinder weldments then are taken to flash removing machines which advance cutters (similar to external broaches in that each successive cutter takes a deeper bite), into the flash and moving parallel with the seam, the flash being removed from both sides simultaneously so the cutting pressures are equal and the cylinder wall does not spring in or out. The cylinders then can be expanded to true size and contour on hydraulic expanders.

Some barrel bodies are made of carbon steel, some of stainless. As a comparison, the stainless is found to be far more temperamental, needs much stronger clamping forces and devices, requires about half the voltage, has about one-third faster welding time, has about 25% as long life between regrinds of the flash cutting tools, and every new type or grade of stainless specified by a customer requires long periods of trial and error in setting up the welders.

The trend of welderies to save money by mechanization is illustrated by a semi-portable projection welder of which several are in use in this shop. Each of these looks like, and has the mechanical action of, a large "C" clamp capable of 1400-lb. pressure between its jaws. Each is suspended from its own monorail by a travelling chain hoist. The monorail permits the welder to be moved from station to station or to be taken from one weldment to another when several are in position for operation and one station, the chain hoist permits quick adjustment for height of work, the welder swings free on its suspension and can be turned or positioned within a narrow radius. The function is to weld braces and other parts to barrels which weigh up to 350 lb. and which usually are handled on roller conveyors. Each projection welder costs some $10,000 installed, but by doing work which formerly required eight arc welding units can save at least $16.00 an operating hour and return its cost in less than 650 operating hours.

Materials for Weldments

A new welding process in a weldery like this one opens whole new avenues to weldment design. The Heliarc process, for example, was adopted in one shop for the seam welding of aluminum. Upon being tried for stainless steel it was proved able to reduce the post-weld grinding cost from a former 95 cents to a present 20 cents per weldment on a single weldment design, and with a very excellent chance that it may remove the buckling trouble formerly encountered.

Where a weldment design calls for welding dissimilar metals, trouble may be found.

The point here is, the metals must be dissimilar in the welding sense. Metals may be as metallurgically dissimilar as steels and bronzes, and yet be easily weldable by wide varieties of welding processes. To give trouble the metals must be welding incompatibles.

Castings of a great many kinds can be difficult to weld. All steels and other alloys begin as castings. But in the rolling and other processes thousands of bad spots are found and eliminated, millions of hair line cracks are compression welded into consolidated metal. Any such faults existing in parent metals, as they are likely to exist in castings, are enemies of good welding.

Castings for welding, then, are preferably poured from electric furnaces or from other closely controlled melting devices, and so molded that there will be the fewest possible areas of sand inclusions and other "dirty metal." Their alloys should be suitable for welding to the metals to which they are to be joined. There are ASTM specifications which give a great deal of guidance regarding this. One of the commonly important points is to keep the carbon content as nearly alike as possible for all parent metals to be welded together.

Forgings are in somewhat similar case. There are special welding grade specifications.

One weldery gave the following rule for selecting stainless steel when this alloy must be welded in large sections to ordinary carbon or other steels:

> Select a stainless which has a coefficient of thermal expansion as close to that of the other parent metal as possible, preferably a stainless stabilized with molybdenum, having low carbon, containing about 20-point aluminum, and being non-air-hardening. Such a stainless can be welded without preheat and needs no subsequent stress relieving.

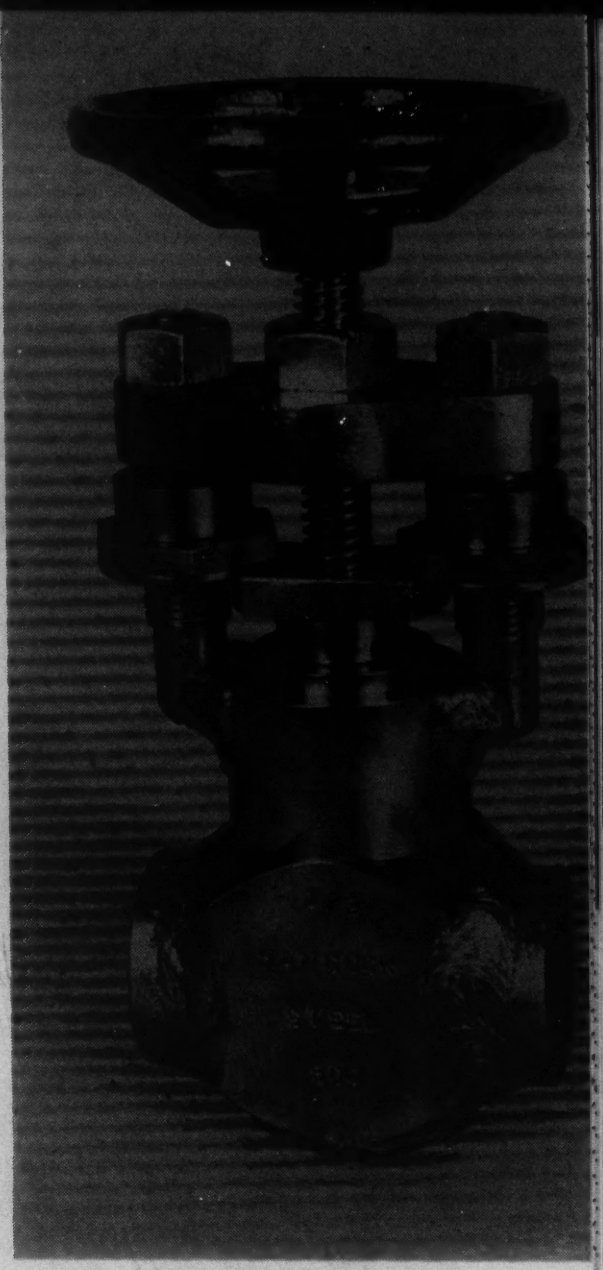
Some incompatible metals are welded by welding between them a third metal which is compatible to both. A case in point is the welding of silver onto steel, then welding

aluminum to the silver.

Most welderies throw up their hands at the mention of gray iron castings, yet all are welding them. They are troublesome when the stresses on the weld zones are tensile. When the stresses are compression or shear the troubles are less. Such castings, then, are welded to low carbon steel to act as sleeve bearings, gibbs, slides, wear surfaces. Often nickel or Monel welding rods, or other methods of creating weld metal which is compatible with the parent metals, is the real secret of the weldment.

The point is, gray iron castings were not primarily invented for purposes of welding. However, the rapid advance of the use of weldments will bring about the creation of special alloys for welding, just as there are special ones for rapid machining, stamping, forging, heat treating. Right now there is a special weldable grade of 18:8 stainless steel; it contains less than 1 point carbon. In this sense "weldability" is the test of the metallurgist. In the opposite sense the possession of the skills and techniques and equipments to weld almost anything is the business of the weldery, and "weldability" becomes a test of the weldery. Welderies will press for the use of the most weldable metals, castings or otherwise, but when a metal or an alloy in the cast or other condition has something important to contribute to the end product they will continue to find ways to weld it.

Precision investment castings, being highly controlled products, usually are easy to weld. One such weldment is an impeller which is used for stirring the pulp in paper mill machines. It is a precision investment casting welded to the end of a carbon steel shaft.



In large valves, weldments are used to replace castings with appreciable savings in weight. (Courtesy: Lincoln Electric Co.)

Castings and weldments often displace each other. In one large electrical company one motor casting has been displaced by a weldment, has in turn displaced the weldment five times, as the foundry and the weldery have improved their techniques and competed for the asignment. In one large foundry and weldery the foundry was having trouble with a base which had to be light and strong. No time could be taken out for experiments; the bases had to be made. A weldment base was designed and the production pressure thus taken off the foundry until the foundry could find the answers, after which production of the weldment ceased and the base became a casting again. A great many weldments are in use because of the severe shortage in castings, and many of the users say they never will go back to the castings, but only time can tell whether or not the weldments will hold the business when castings again are plentiful.

Advances in weldments which consist of larger bodies of "strength metals" and rod welded surface deposits of "service metals" now include thousands of different items, soon will include hundreds of thousands in which surface wear or corrosion means that an item no longer is useful. Items include chisels, toolbits, twist drills, centerless grinder work rests, hoes, plows, helicoid conveyor flights, even an axe which has been tipped with tool steel and is used in a junk yard for chopping off steel rods up to ⅜-in. dia. Punches and dies are made by forming thin sections of ordinary steel, hard surfacing these by welding, grinding to true dimensions, then mounting the weldments on hydrolized wood die block stock. Such dies are relatively inexpensive and long lived. The weldments which make them will cause stampings to displace other weldments.

Typical Applications of Weldments

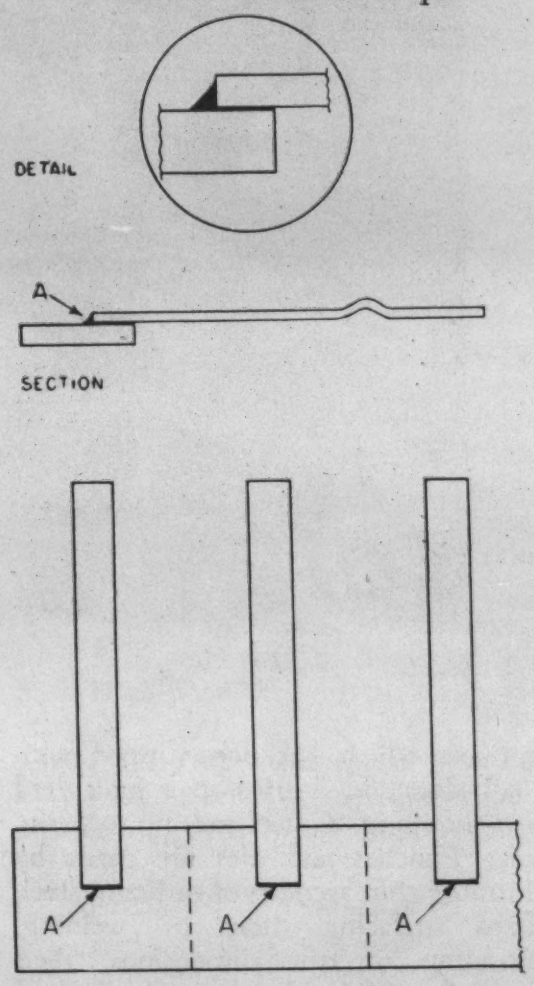
Weldments often consist of a welding process employed to make other fabricating processes more applicable. An example is an 800-lb. pressure for 750 F service Manning Maxwell & Moore "Hancock Weldvalve" valve made in IPS sizes ranging from ¼ to 2 in. Here the function of arc welds is to make possible the use of automatic screw machines for making small valve bodies which formerly were made one at a time from small castings. The steel is SAE 1020. The operations:

(1) Machine main body.
(2) Broach hole to higher accuracy.
(3) Machine yoke posts.
(4) Machine seats, threading to sizes desired.
(5) Produce flat disk caps.
(6) Hard face seats by welding.
(7) Assemble seats in body by arc welding.
(8) Assemble yoke posts to body by arc welding.
(9) Assemble cap to body by arc welding.

It will be seen that for one size of body a total of three automatic screw machine set-ups with minor tool variations are sufficient, the method of producing the cap not being specified. Six simple welding operations are needed. The final assembly has an additional tack weld to assure that the thread bushing is not accidentally turned out of adjustment.

Machine guard weldments often make the welding process a mere adjunct of the products of stamping, forming, flame cutting and other

equipment. The necessary pieces of parent metal are stamped or cut to size and then, as needed, are formed to shape, after which they are welded, usually by arc welding. The usual result is a reduction of weight and cost of the guard. Special sections can be welded on for lubricating, to act as lubricant drains or tool holders or catch basins for dusts and chips.



This illustration shows how electrical contact parts are welded to mild steel strips. The strips are later cut (dotted lines) to make individual contacts.

Many weldments are multiple parts which later are cut apart by stamping machines, shears or friction saws to make the desired individual parts. An example is an electrical contact the main body of which is mild steel and the electrical spring contact a copper-steel alloy. Rows of the contact parts are arc welded to steel strips so the contact parts resemble the teeth of combs, then the mild steel strips are cut transversely so each contact becomes a single piece with its mild steel base. The mild steel can be punched or drilled for final assembly as desired.

Assembly of laminations for electrical machinery is now being done by arc welding at the Lincoln Electric Co. plant. In this, simple square notches which can easily be stamped in the edges of the lamination plates are substituted for the usual round holes through the main bodies or areas of the plates, the stamping operation thus being made somewhat less costly. Simple and inexpensive strips of soft steel, with both ends bent over at 90-deg. angles, fit into the edge notches and replace the long and costlier through-bolts which are passed through the round holes in most such assemblies.

Welding is done in a hydraulic fixture which presses the laminations together with the pressure formerly obtained by tightening the nuts of the through bolts, the lengths of holding strips being carefully controlled so they can fit into the aligned notches of the plates and over the end plates only when the assembly is fully compact. Whereas pressures obtained by tightening through-bolts are highly variable and depend largely upon the "feel" of the wrench, informing the operator as to just when he has all tightnesses alike, both the lengths of the holding strips between their turned over ends and the hydraulic pressure used in compacting the assembly are subject to strict mechanical control and the pressure of the compactness of the plates therefore is a known quantity. Welding the holding strips in place is the final operation.

Assembly weldments consisting of one material intended to conduct electricity and another to supply strength or shock resistance at low cost are growing in number. High silicon steel strip selected for its electrical properties is welded to shapes of a dead soft stock selected for its low cost and its complete formability in presses. Copper steel selected for conductivity and for abrasion resistance is welded to steel jaws stamped out of heavy plate, then the weldment is copper plated to give it an even color and make it rust resistant. Armco ingot iron to carry electrical flux is made the cores of solid rollers which are faced with SAE 4130 steel strip stock on their peripheries. The 4130 is rolled to circular shape, arc welded into ring weldments, rough bored to size, forced over the Armco cores, welded in place. With such rollers the 4130 takes the abrasive wear, and by varying its thickness rollers of different diameters can be made while only carrying one diameter of the core material in inventory.

Assembly weldments which are made almost casually along the production line but solve important problems of shop adjustment and of field repair are growing in popularity.

In one instance a nut on a shaft opposes a coiled spring which in turn holds in place a part which must be located exactly under normal load against it but which must move axially along the shaft to reposition itself for overloads. In the original design the shafts were threaded and the springs, which are likely to have somewhat variable resiliencies, were brought to proper compression by careful adjustment of the nuts.

It was found that if this nut was adjusted early in the assembly sequence when adjustment was easiest to make it was likely to be moved out of adjustment as further assemblies were added. A costly final adjustment at the end of the assembly line therefore was made. And in field repairs there was a tendency to move the nut out of adjustment. Consequently, a secondary development stage of the design called for making all parts to close limits, paying the extra costs of obtaining springs of exactly controlled resiliencies, and machining a shoulder on the shaft so that when the nut bore against the shoulder the spring would be in adjustment. This was high in cost and unsatisfactory mechanically.

The final design stage called for abandoning the shoulder and the close limits, adjusting the nut at the assembly stage where it was easiest to do, arc welding the nut in place so it could not be moved or maladjusted. Then it was observed that threading the shaft no longer was necessary, that the nut could be moved by hydraulic or pneumatic pressure along the bare shaft machined to a size to fit its bore, and when the gages showed the spring pressure to be ideal, the welding could be done. Threads inside of the nut obviously were no longer needed; a welded collar now does the job.

Another instance was that of a turnbuckle which connects two rods. Anyone who has handled such a device knows that it can be a vexatious assembly problem in that the rods must be separated the full distance of their travel in order to be entered into the buckle and that their eye ends therefore seldom can be attached to the device to be tightened unless the buckle and rods first are assembled. In this machine it was desired to attach those eyes to the parts which the turn

buckle would connect several assembly steps in advance of making the actual connection.

The problem was solved by making the buckle of three parts. These were the left threaded end, the right threaded end, and the buckle body. The rods were attached at the most convenient assembly stage, the threaded ends were placed on them and turned to the limits of their travels. In final assembly the body was passed over the end of one rod and moved along until the other rod could enter it, the threaded ends were adjusted along their rods until they met and held the body in fairly central position, the threaded ends were arc welded to the body so the body became a buckle. The welds were of more than 100% efficiency, therefore the weld areas had greater strengths than any other areas of the buckle.

Ring and other weldments which make forging processes more useful and economical for high cost high carbon alloy steels were known somewhat before the war but are being made in large quantities and wide varieties today.

An example is a flanged forging made of NE 52100 "ball bearing" steel. To make this by forging processes alone would entail many high cost operations on a material which is difficult to forge, and result in a waste of expensive stock.

Rectangular bars of the material are cut to length and their ends dressed to a fair degree of smoothness and to a special angle which will cause them to meet at their peripheries when rolled into rings. Dressing also removes all oxides. The lengths are formed to circular shapes, mounted in the hydraulically operated grips of the welding machine, and oxyacetylene flames are carefully positioned and controlled to simultaneously heat all exterior areas of the weld zone to plastic temperature. When the stock is ready the hydraulic pressure is applied and a compression weld is completed.

When the upset has proceeded for a predetermined distance a weld which is very close to the cross crystallization type is known to have been produced. After stress relieving, the ring is expanded to size on a hydraulic expander and this, as usual, acts also as a test of the efficiency of the weld.

Heating of this ring weldment to forging temperature accomplishes still further stress relieving if any is needed. The weldment now is a forging blank but is of the size and shape to which several forging operations might have brought it. Final forging serves to produce the final piece, and the forging forces plus any subsequent heat treatment serve to bring complete cross crystallization, the weld zone then becoming metallurgically indistinguishable from any other area of the forging.

Another oxyacetylene process which recently has been announced would permit the stock to be forged in the straight flat condition to non-symmetrical shapes, or to be rolled to shapes other than round or rectangular, then to be formed to the ring shape, welded with cross crystallized weld, and then to be forged to final shape if further forging were needed. This process introduces the oxyacetylene flames between the ends of the formed ring, the ends being left apart for the purpose. When the end surfaces reach fusion or other preselected temperatures the flame head is withdrawn and the ends forced together. The process is independent of the cross-sectional shapes of those ends since the flame pattern can be varied to the needs of any cross sections. This process is new; it has had very little field testing. But it is certain to make changes in the operational sequences of weldment forging procedures and to greatly increase the utility of weldments as simplifiers of forging procedures.

Ring weldments exist in thousands of sizes and types. Seam welded pipes and tubes, for example, are common forms of ring weldments.

The supposition that the weld zone is the weakest part of the ring and that welds are to be avoided in ring shapes, is dying a slow but steady death in the face of the ability to produce welds of more than 100% efficiency. As this false idea passes out, the making of rings having two or more weld zones instead of only one is growing. The cost of welding now is compared to the costs of forming and of other processes, and the lowest cost combination of processes is adopted.

The gear toothed rim of a large gear, for example, was made of a single bar of steel which was formed into ring shape, arc welded where the ends met, placed in the gear generating machine in such position that the weld zone would come between two teeth and so would bear little stress, the teeth were cut, and the finished ring gear was welded to the periphery of a disk of steel plate which had been flame cut for the purpose and which served as the web.

Experience showed that the weld zone never gave any trouble and that therefore there was no reason why more than one such zone should not be present.

Gear ring segments therefore are made in this shop in two pieces, three pieces, one piece or whatever number proves most economical when the costs of forming are balanced against those of welding. Half circles can be stamped or formed on punch or draw presses, only the pieces of more than 180 deg. need the somewhat slower bending machines.

Many attempts were reported at automatic arc welding of narrow ring sections. In all cases the welds tended to be faulty where the rod entered and where it left the weld zone, thus producing welds too low in efficiency and quality. One solution of this was to make the rings from wide plates rather than from narrow strips. The plates are slotted very nearly to their ends, the slots being parallel to the intended peripheries of the rings and being so spaced that the widths of metal between them are those of the desired rings. The slotted plates then are bent into cylindrical shapes and the continuous areas of metal at their ends are arc welded so that the plates become cylindrical weldments. Cutting the short distance through the weld zone from one end to the other of the same slot serves to sever a complete ring weldment from its fellows. But the problems of automatic arc welding of narrow sections undoubtedly will be solved in the near future, making this method unnecessary.

Such a method is, of course, available only to welderies having bending machinery capable of forming the wide and thick plates involved, or able to subcontract the services of such machines from shops having them.

Electrical flash and resistance compression ring weldments, and the fact that with post-weld heat treatments the rings can be completely cross crystallized, have been described in other sections of this manual. Due to electrical phenomena which sometimes tend to produce different current conditions at the periphery than at the bore of a ring, these often are originally so formed that their main bodies are circular but their free end sections are

straight and when pushed together for welding and compression will meet as straight flat pieces travelling in the same plane. Advantage then is taken of the hydraulic expansion process to form the weldment into a completely circular ring. This resource, like so many others, is open only to welderies which make enough ring weldments so it has paid them to invest in the necessary expanders.

Although the greatest tonnage of ring weldments undoubtedly will continue to be electrically welded—seam welded pipes and tubes alone should establish that—the greatest number of sizes, shape variations and alloy contents will for the present be arc welded or gas-and-rod welded. More advantage will be taken of the abilities of the almost bewildering variety of rods available on the open market. Rods and welding techniques can be had which will cause the welds to match almost any strengths, machinabilities, deformabilities, heat treat abilities, corrosion resistances, etc., of the parent metals. Rod welded rings seldom are expanded on the hydraulic expanders to obtain the high accuracies which the expanders can give, but there is no reason why they should not be. Rod weld rings have been used in helical gears in which the weld zones cannot be kept wholly at the tooth roots but must inevitably cross areas of whole teeth, and there has in these cases been no sign of the weld area teeth wearing, deforming or otherwise giving trouble to any greater extent than the other teeth. Rod welded rings have been used as heavy compression rollers, and subjected to severe abrasion service, without the weld areas wearing any more rapidly than the parent metals.

The Future

Welding equipment is rapidly progressing into the machine tool stage. Spot, seam and projection welders long have been rigged like turret lathes so the simple turning of one or more index heads will selectively bring different welding heads into position for different operations on the same part or for permanent set-ups for different parts which are made on the same production lines. A lubricant specialty business similar to the cutting oils business is growing up to supply such machines with lubricants which are heat resisting and are good electrical conductors. The thousands of designs of weldments now made by these processes will be multiplied.

Steel sheets 1-in. thick have been spot welded without serious marring of their surfaces, although no examples of doing this on a production scale were seen. A new spot welding machine at a single closing of the dies simultaneously makes all of the welds necessary for the main structure of an automobile door; special stampings dies to prepare door sections for its services had to be made. Other spot and projection welding machines simultaneously make dozens of tack welds in nonferrous metal parts which are difficult to weld without buckling or marring. These metals have somewhat dissimilar thermal coefficients of expansion, but large and thin sections are held against relative movements by the tack welds while the parts are hydrogen furnace brazed together.

Semi automatic and even fully automatic arc welders are appearing in welderies in large numbers. They make use of fluxes, feed the rod in coil form instead of straight pieces, are guided either manually or by cams or pantographs, make use of much higher current densities and so produce less of residual strains by working at higher speeds and getting fewer BTUs into the parent metals. Sometimes such welders feed two or more rods or wires at the same time and so either reduce the total welding time or permit the automatic control of welding procedures which will still further reduce residual stresses. However, as machine tools these devices are in their infancies. Any experienced production man, watching one of these in action, can see that although in their present forms they are reducing the costs and increasing the utilities of hundreds of different weldment designs, in the forms which they will take ten years from now they will be a thousand times more effective and useful. The intervening period will be taken up with experiment and experience.

Several large welderies said that when, after a few months of the present day delays, they had obtained and installed the new equipment which now is on order, they would announce greatly expanded and diversified capacities. Several developers of welding processes and equipments said that the announcements of brand new methods and resources for welderies are only being held up by the same delays of equipment and materials; the first production installations are just now being made.

With the new scientific papers which are due on stress relieving and other subjects, the advance of the weldery and of the weldment as tools of industry will be rapid.

Acknowledgement

Grateful acknowledgement is hereby given to the following companies and organizations who cooperated in supplying information upon which this manual was based.

Air Reduction Co.
Warner & Swasey Co.
American Welding & Mfg. Co.
M-L. Bayard & Co.
Cleveland Welding Co.
Dresser Industries, Inc.
Federal Welder Co.
Graver Tank & Mfg. Co.
International Nickel Co.
Linde Air Products Co.
Lincoln Electric Co.
Lukenweld, Inc.
R. C. Mahon Co.
Republic Welding & Flame Cutting Co.
Resistance Welders Mfg. Assn.
A. O. Smith Corp.
S. Morgan Smith Co.
Stevens Metal Products Co.
Taylor-Winfield Co.
United Welding Co.

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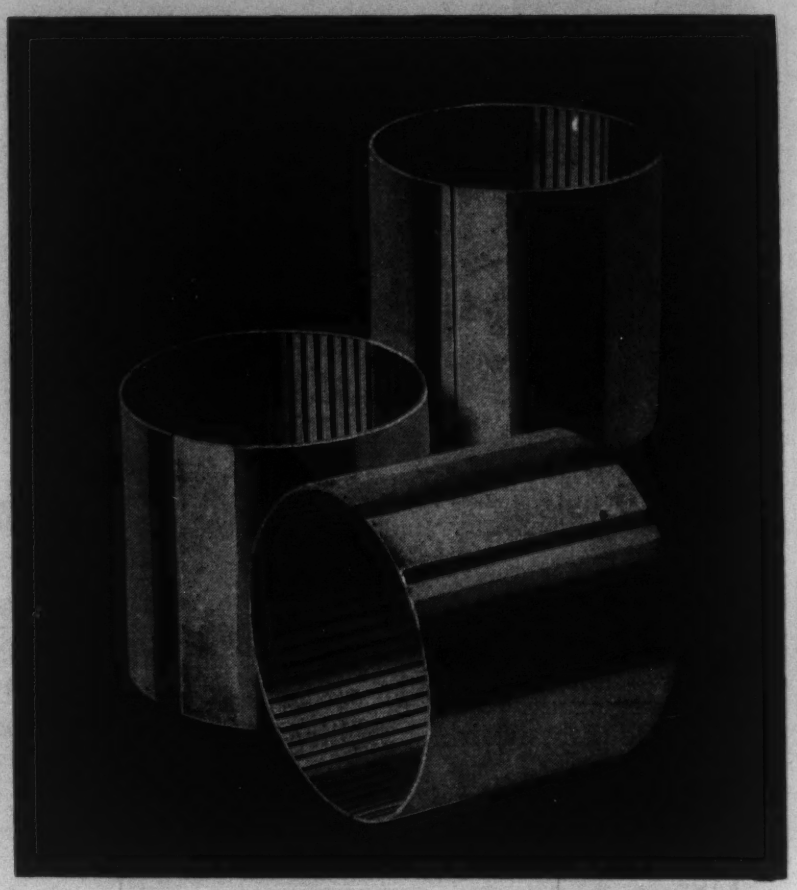

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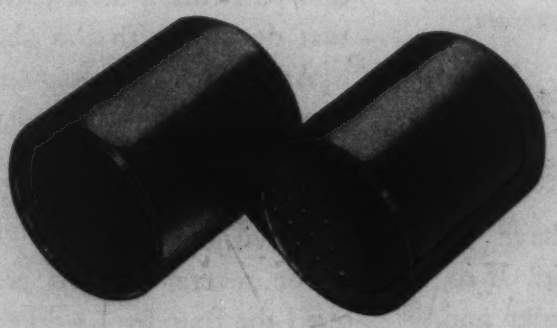

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CONTENTS NOTED

A monthly department dedicated as a forum for the interchange of ideas between readers and editors. All readers are urged to take advantage of this space and participate in the discussions presented.

MATERIALS & METHODS Manuals

To the Editor:

I am very much impressed with the Manuals you publish in MATERIALS & METHODS and often would like to have them available for filing. Why don't you publish these separately or put them in the magazine loose so they can be removed without difficulty?

D. H. D.

Milwaukee, Wis.

Reprints are made of all of the MATERIALS & METHODS *manuals immediately after they have appeared in the magazine. Such reprints are available within three or four weeks after publication date of the issue. A slight charge is made (25 cents) for each copy to cover handling costs. With the exception of a few of the earliest manuals, reprints are still available of all 23 manuals published through the one in this issue on Weldments.—The Editors.*

M & M—A Masterpiece

To the Editor:

Please accept my heartiest congratulations on your November 1946 issue of MATERIALS & METHODS—it is truly a masterpiece.

I am making no apology for my mentality when I tell you that to me the most interesting parts of the magazine were the advertisements, not only because they were so richly illustrated, but because they were so replete with metallurgical, chemical and mechanical discoveries that have been put into practical and productive uses. They show so clearly what has been achieved in the progress of materials and methods.

Ralph Sweetser

New York, N. Y.

Although we editors have a certain sensitivity about this matter, we must agree that a large percentage of advertising carried in MATERIALS & METHODS *serves to augment information we publish in the editorial sections. We are pleased to hear that our November award issue was so well received by Mr. Sweetser and many other readers.—The Editors.*

The Achievement Award

To the Editor:

Are you planning to have an Achievement Award this year? If so, what do I have to do to enter and what are the rules? My company has done what I think is some outstanding work in making our products better than they formerly were and still reducing the manufactured cost.

R. B.

Philadelphia, Pa.

Perhaps reader R. B. has by now seen the announcement of our 1947 Achievement Award competition which appeared in the January 1947 issue of MATERIALS & METHODS *(pages 56 and 57). Anyone thinking that he, his company or one of his customers has done an exceptional job is invited to submit entries. This year's theme is . . . "the significant use of modern engineering materials and processing methods to increase production and reduce the cost of products now being manufactured." Entries must be in by June 30, 1947. —The Editors.*

Glass Working

To the Editor:

A bouquet for your Production Frontiers in the November issue of MATERIALS & METHODS. One item that particularly struck my fancy was that dealing with the glass workers.

And what possible interest, see you, can an old molder have in glass working?

A fair question, deserving a fair and civil answer.

For several months before I entered the foundry I worked in a glass factory. My job was to carry the glass pitchers from the press to a crabby old Englishman who sat on a bench and formed the spout and attached the handles. He was an old crab and kept a can of beer under the bench, but he was an artistic and highly skilled craftsman. If this little crumb of ancient history (1890) will do you no good, at least it won't do you any harm.

P. D.

Cleveland, Ohio

NUMBER 131
February, 1947

MATERIALS: Magnesium Alloys
METHODS: Welding

Weldability of Magnesium-Base Alloys

Magnesium-base alloys, both wrought and cast, can be joined by either of two common welding processes: (1) fusion, and (2) resistance welding. The types of fusion welding methods having the widest range of application are the oxyacetylene and tungsten arc processes. Resistance methods in common use are seam, spot and flash or butt welding.

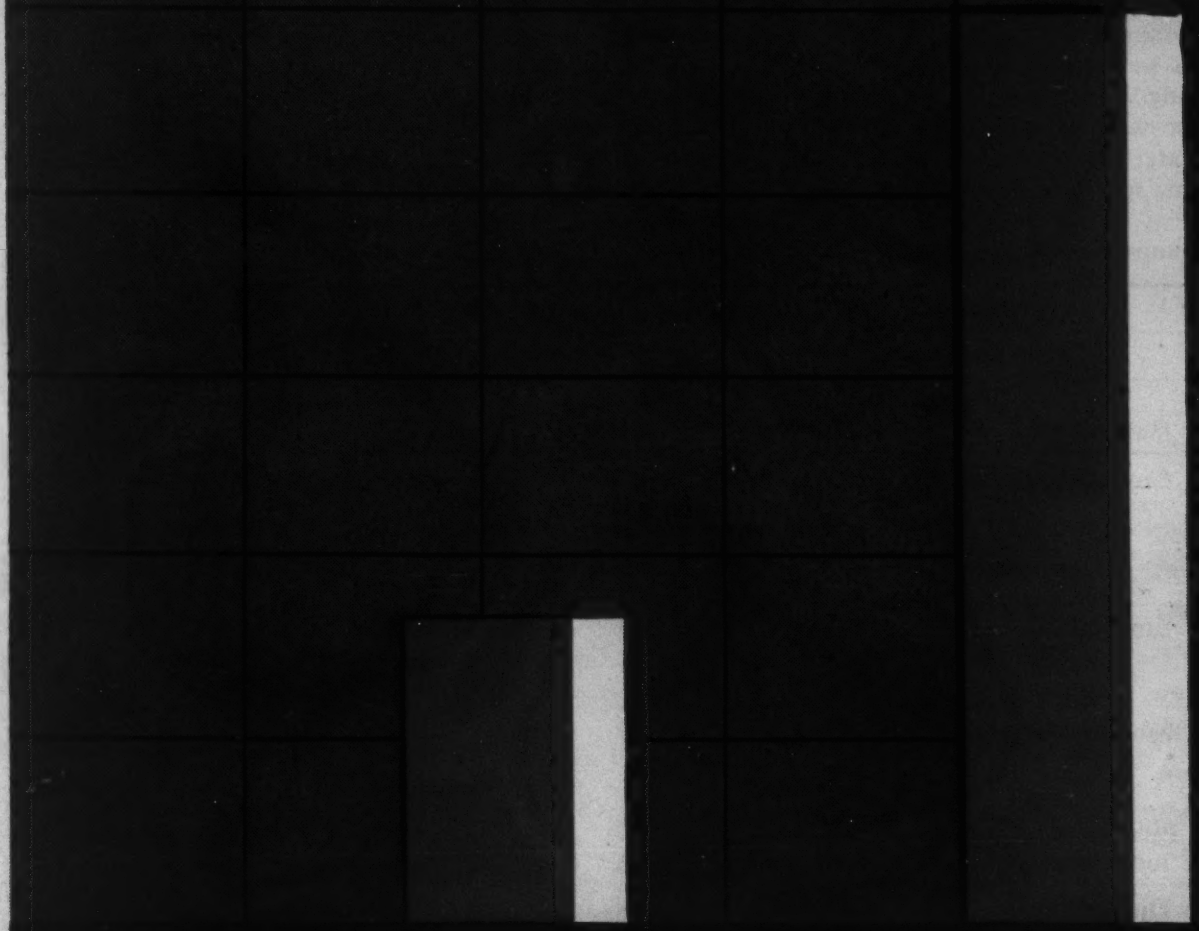
The following table gives a comparison of the relative weldability of some of the common magnesium-base alloys. The weldability rating of each alloy is indicated by numbers from 1 to 4, number 1 denoting the best rating (widest adaptability and greatest ease of welding) for a particular welding process. Symbol "X" indicates that a feasible commercial welding process has not yet been developed. These data were taken from a publication of the American Magnesium Corp.

Commercial Material Specification	Welding Processes (4)						
	Oxyacetylene			Electric Arc (1)		Resistance (2)	
	Material Form	Weldability	Remarks	Weldability	Remarks	Weldability	Remarks (3)
ASTM B80-45T, Alloy A12	Sand castings	X	—	X	—	X	—
ASTM B80-45T, Alloy AZ63 SAE 50; AMS 4420, 4422, 4424	Sand castings	4	Fittings can be welded into sheet structures	4	Fittings can be welded into sheet structures	1	Easily spot-welded
ASTM B80-45T, Alloy AZ92 SAE 500; AMS 4434	Sand castings	4	Fittings can be welded into sheet structures	3	Fittings can be welded into sheet structures	1	Easily spot-welded
ASTM B80-45T, Alloy M1	Sand castings	1	Fittings can be welded into sheet structures	2	Fittings can be welded into sheet structures	1	Easily spot-welded
ASTM B199-45T, Alloy A10 SAE 502	Permanent mold castings	4	—	2	—	1	Easily spot-welded
ASTM B94-44T, Alloy AZ90 SAE 501; AMS 4490	Die castings	X	—	X	—	X	—
ASTM B90-45T, Alloy AZ31X ASTM B107-45T, Alloy AZ31X SAE 52, 510	Sheet and extruded rods, bars and shapes	2	Weldable in relatively short seams	1	Weldable within a wide range of operating conditions	1	Can be spot, seam and flash or butt welded
ASTM B90-45T, Alloy AZ51X SAE 512	Sheet and strip	2	Weldable in relatively short seams	1	Weldable within a wide range of operating conditions	1	Can be spot, seam and flash or butt welded
ASTM B90-45T, Alloy AZ61X SAE 511; AMS 4380, 4381	Sheet and strip	3	Weldable in short seams	1	Weldable within a wide range of operating conditions	1	Can be spot, seam and flash or butt welded
ASTM B90-45T, Alloy M1 ASTM B107-45T, Alloy M1 SAE 51, 522; AMS 4370	Sheet, strip and extruded rods, bars and shapes	1	The most commonly used alloy for gas welding	1	Weldable within much narrower limits than above alloys (welding speed and current control are critical factors)	1	Can be spot, seam and flash or butt welded
ASTM B91-45T, Alloy AT35 SAE 53	Forgings	2	—	3	—	2	—
ASTM B107-45T, Alloy AZ80X SAE 523	Extruded bars, rods and shapes	4	Not generally recommended	3	Requires greater speed and welding currents than does ASTM B90-45T Alloy M1	1	Forms high strength welds under properly controlled conditions

(1) A tungsten arc protected by an envelope of inert (helium) gas (the "Heliarc" process) is used; no flux is required
(2) Includes spot, seam and butt or flash welding
(3) Magnesium-base alloys can be spot-welded together but they cannot be spot-welded to other alloys
(4) Magnesium-base alloys generally cannot be satisfactorily welded to other alloys; neither can they be cut with a torch

Compiled by Robert S. Burpo, Jr.

Lustron unlimited: 1947



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MONSANTO PLASTICS

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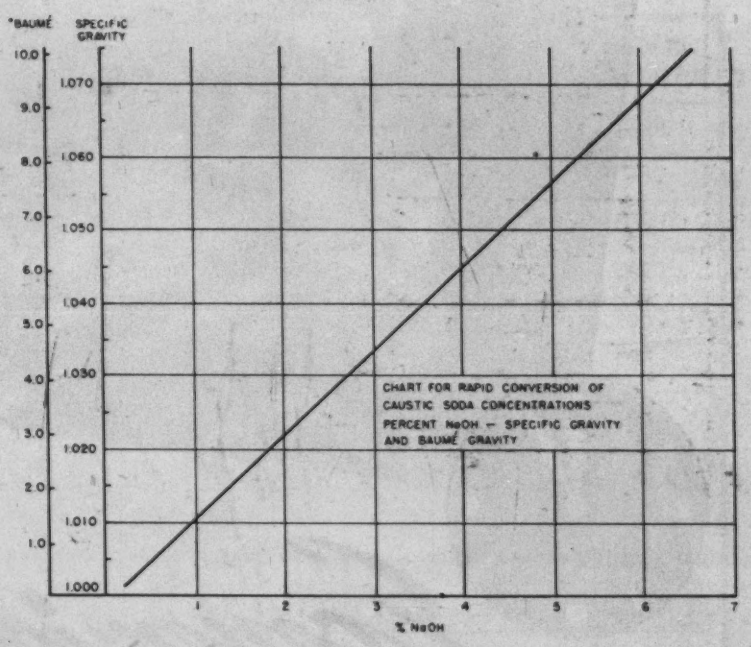
NUMBER 132
February, 1947

METHODS: Heat Treating
MATERIALS: Steel Forgings, Etc.

Caustic Soda Solutions

Use of caustic soda solutions for quenching in the heat treatment of forgings and other work presents definite advantages. The solutions usually used are of strengths varying from about 2.5% to about 6.5% caustic soda. It is frequently helpful to make up and to check these solutions with a hydrometer, as the simplest means of determining concentration. The tables and curves here given are intended to help make up such solutions by weight to desired strengths, or to check solutions already made up, using a hydrometer reading in either specific gravity or Baumé degrees.

% NaOH	Lb./N_2OH/Gal.	Specific Gravity	° Baumé
0.61	0.050	1.007	1.0
1.20	0.100	1.014	2.0
2.00	0.170	1.022	3.1
2.70	0.233	1.029	4.1
3.35	0.292	1.036	5.1
4.00	0.350	1.045	6.2
4.64	0.409	1.052	7.2
5.29	0.467	1.060	8.2
5.87	0.525	1.067	9.1
6.55	0.584	1.075	10.1
7.31	0.659	1.083	11.1
8.00	0.726	1.091	12.1
8.68	0.792	1.100	13.2
9.42	0.867	1.108	14.1
10.06	0.934	1.116	15.1
10.97	1.025	1.125	16.1
11.84	1.117	1.134	17.1
12.64	1.201	1.142	18.0
13.55	1.301	1.152	19.1
14.37	1.392	1.162	20.2
15.13	1.476	1.171	21.2
15.91	1.567	1.180	22.1
16.77	1.668	1.190	23.1
17.67	1.768	1.200	24.2

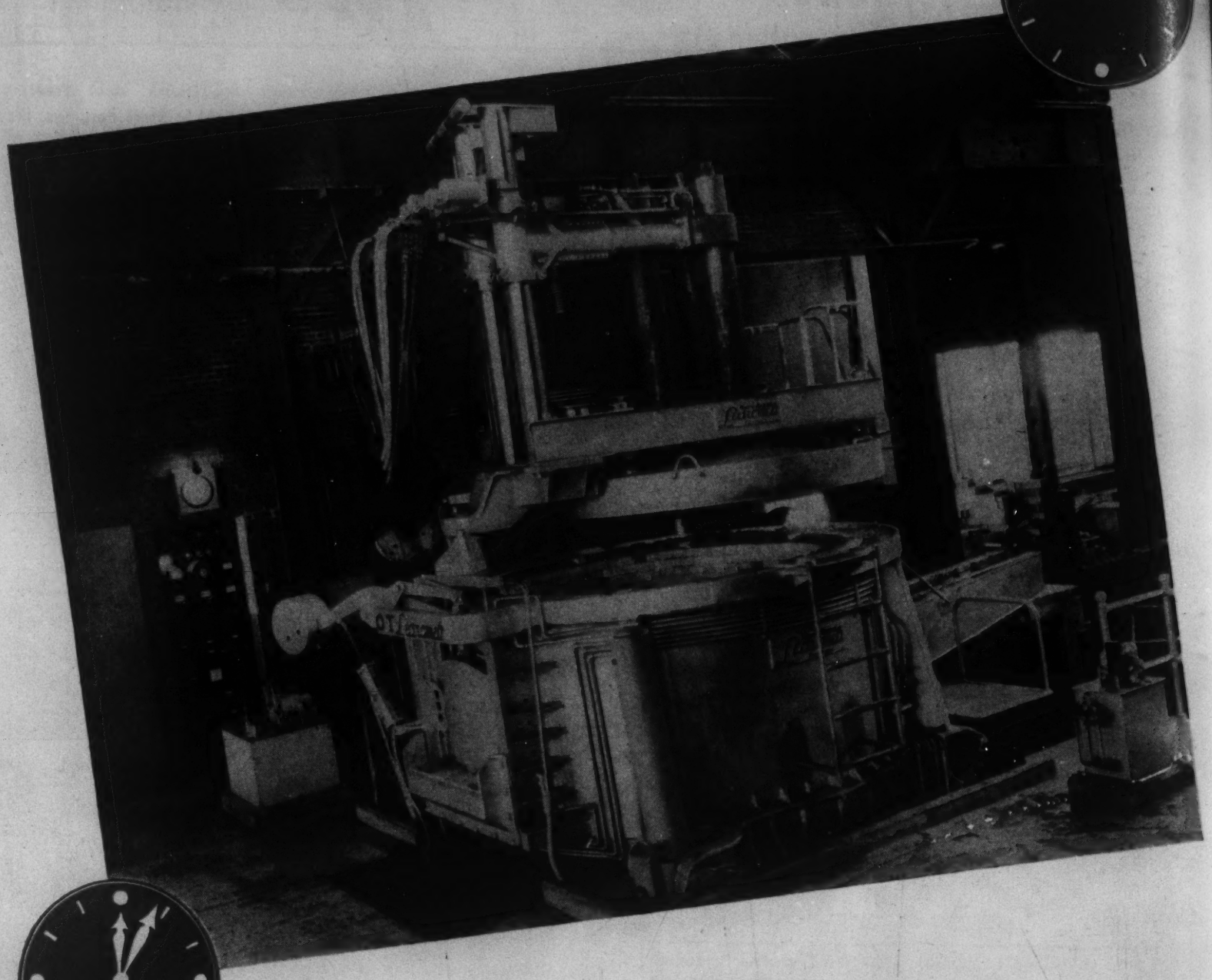


The tables can also be used to determine the amount of caustic to be added to a solution that has become diluted, using the hydrometer reading to determine present concentration in pound of caustic per gallon, and determining by difference the amount of caustic to be added to bring the concentration to a desired percentage strength, expressed in pound per gallon. The tables are based upon solutions at 60 F.

Hydrometer readings to determine the concentration of caustic solutions do not indicate the purity of the solution, but only its specific gravity. Thus, if part of the caustic has been changed to carbonate by absorption of carbon dioxide from the air, the hydrometer reading would give no evidence of this deterioration.

Compiled by Kenneth Rose, Engineering Editor

MORE TONS PER TURN



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MOORE RAPID *Lectromelt* FURNACES

PITTSBURGH LECTROMELT FURNACE CORPORATION
PITTSBURGH 30, PENNA.

NUMBER 133
February, 1947

Stability of Alloys to Oxidizing Atmospheres

Temperatures given are those below which scaling losses are less than 0.0002 to 0.0004 gm. per sq. cm. per hour.

Material	C	Cr	Mn	Si	Ni	Al	Fe	Cu	Zn	Co	Stable to Deg. F in Air
Copper								Bal.			842
Iron							Bal.				932
Brass								70	30		1292
Nickel					Bal.						1472
Chromium											1652
Iron-Chromium Alloys	0.1 - 0.2	4. - 6.	0.5	0.5			Bal.				1202
	0.15	8. - 10.	0.5	0.5			Bal.				1382
	0.10	12. - 14.	0.5	0.5			Bal.				1382 - 1472
	0.10	16. - 18.	0.5	0.5			Bal.				1562 - 1652
	0.10	25. - 30.	0.5	0.5			Bal.				1922 - 2012
Iron-Chromium-Nickel Alloys	0.1	17. - 19.	0.5	0.5	8. - 10.		Bal.				1562 - 1652
	0.2	17. - 19.	0.5	3.0	25. - 26.		Bal.				1922 - 2012
	0.15	22. - 28.	0.5	0.5	12. - 16.		Bal.				1832
	0.15	24. - 26.	0.75	1.0	19. - 21.		Bal.				1922 - 2012
	0.15	15. - 20.	0.5 - 1.0	1.0 - 2.0	30. - 35.		Bal.				1922 - 2012
	0.1 - 0.5	14. - 18.	1.0 - 2.	1.5 - 2.	60. - 65.		Bal.				1832 - 2012
	0.15	12. - 20.	2.	2.	70. - 80.		Bal.				2012 - 2102
Chromium-Nickel Alloys	0.25	19. - 20.	2.5	0.5	77. - 79.		Bal.				2102
Chromium-Aluminum-Iron Alloys	0.10	5. - 6.5	0.45	0.5		0.6 - 0.8	Bal.				1472
	0.10	6.5 - 8.5	0.45	1.0		1.2 - 2.0	Bal.				1652
	0.12	12. - 15.	0.5	0.5 - 1.0		2.5 - 3.5	Bal.				1652 - 1832
	0.12	18. - 20.	0.5	0.5 - 1.0		3. - 4.	Bal.				2192
	0.10	20. - 22.	0.5 - 1.5	0.5		3. - 5.	Bal.				2282 - 2372
		20.				5.	Bal.			1.5 - 3.0	2102 - 2272
	0.1	30.	0.5	0.5		5.	Bal.				App. 2425

Data supplied by Benjamin Lustman, Research Laboratories, Westinghouse Electric Corp.

Welded Design Cuts Machine's Cost 60%

BY H. H. STAHL, DISTRICT MANAGER AND WELDING ENGINEER, THE LINCOLN ELECTRIC CO., BOSTON, MASS.

A striking example of a present-day trend in machine design is the evolution of a strawboard shear machine made by Hobbs Manufacturing Co., Boston, Mass.

Redesign of this machine for fabrication by electric arc welding resulted in a machine with a weight of only one-third that of the original and costing 60% less to produce.

In the former design (see Fig. 1), the various parts of the shear were made in individual pieces and had to be hand-fitted, drilled and bolted. All of these operations were eliminated by the welded design (see Fig. 2), which utilizes rolled steel in standard angles and plate sizes.

THE DESIGN PROBLEM

In changing over the design to welded steel construction, the manufacturer analyzed the load requirements of the frame which consists essentially of four legs acting as columns and braces acting as beams. Resistance to deflection was the main consideration.

FIG. 1—OLD DESIGN. *This shear was made in individual pieces that had to be hand-fitted, drilled and bolted. Line production system was impossible.*

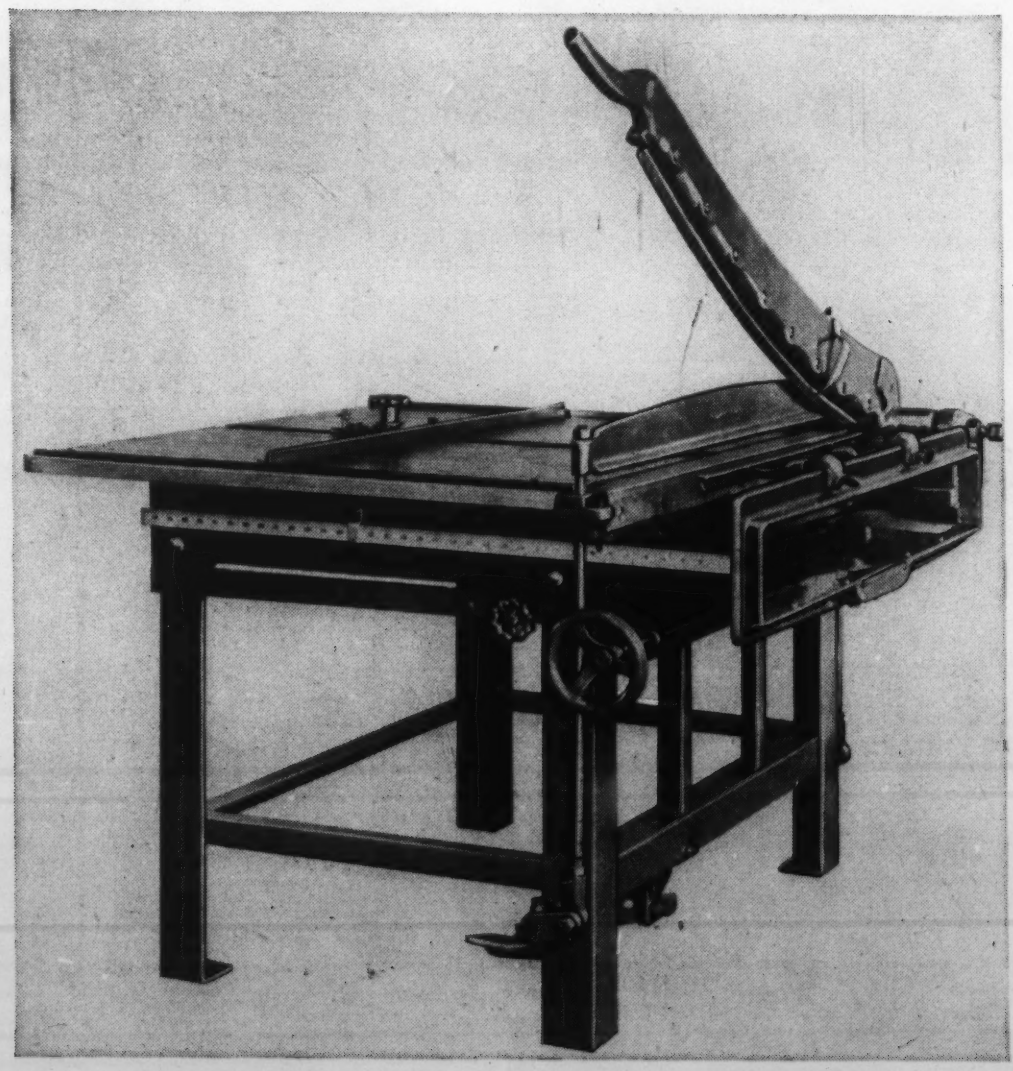

FIG. 2—WELDED DESIGN. *Hobbs engineers redesigned the shear for fabrication by arc welding. The new machine costs 60% less, weighs two-thirds less and is made by line production methods.*

For example, in studying the problem in light of the usual beam formula (see Page 496, 8th Edition, Lincoln Procedure Handbook), comparison can be made of the size of steel angles needed to replace the old material.

In simple designs such as this, however, the common sense formula, based on experience, should prevail. Sizes of members should be governed also by uncalculable demands of handling and shipment, when the machine often gets its roughest treatment.

PRODUCTION PROCEDURE

The simple angle iron and plate design of the frame (see Fig. 2) permits a standardized line production. Angles and plate are shear cut to size, are fitted up in a simple welded fixture and tack welded. All joints are fillets or square butts, requiring no bevelling. Tacked assembly is then placed in a positioner and finish welded . . . all joints downhand for maximum speed. A little grinding off of corner welds of top table and drilling for attachments is all the machining that's required.

A series of Studies in Machine Design are published by The Lincoln Electric Company and are available without charge to engineers and designers. They may be obtained by writing THE LINCOLN ELECTRIC COMPANY, Dept. 241, Cleveland 1, Ohio.

MATERIALS & METHODS DIGEST

A selective condensation of articles—presenting new developments and ideas in materials and their processing—from foreign journals and domestic publications of specialized circulation.

Edited by H. R. CLAUSER

Hard Wear-Resisting Cast Irons and Steels

Condensed from "Foundry Trade Journal"

Knowledge of the subject of friction and resistance to wear is still very limited. At the present time, the choice of material is governed by the analogy of similar cases and by the use of rules, which cannot be explicitly stated, because they are subject to so many exceptions. One of these rules is that hard materials should be used where rapid wear is involved, but it is well known that certain wear problems have been solved by the use of austenitic steels with 13 to 15% manganese, which have only a moderate ball hardness.

There are various solutions that are available to the problem of obtaining a hard cast iron, resistant to wear.

Gray cast irons can be used for the following purposes. Those of a sorbitic structure as-cast, with no heat-treatment and with alloy elements added to the cast iron, increase the level of hardness. A very wide range of components have been made in cast iron, machinable "as cast," quenched and tempered, including: motor cylinder liners, gears, shaping and stamping dies, etc.

In the tempered condition, the casting being martensitic, one of the first applications in France was the Potez aero engine cylinder in 1930. The first cylinders had been made of ordinary pearlitic iron, but their performance was not satisfactory, owing to the fairly high compression in these engines. When made in this cast iron, the cyinders had in the as-cast conditions a gray martensitic structure with a Brinell of 360 to 400. Results of the same nature, but much more important, have been recently obtained with cylinder blocks for engines for tanks and for Diesel engine locomotives.

The hardness specified for the casting "as cast" was 360 Brinell minimum. The average hardness obtained has been from 380 to 420.

Hardening and tempering of cast iron, austenitic in the as-cast condition, was used in the production of steam engine slide valves and drill guides. The field of cast irons with high carbon, 3.5 to 4.0%, does not seem to have been sufficiently explored. It would, however, seem of interest to use cast irons containing a large amount of graphite, as this element is very useful against friction. Another group of cast irons, still not well known to founders, is the white cast irons. With non-alloy white irons, the possibilities are very limited since modification can be affected only by change in carbon content, and both hardness and brittleness increase with increase in carbon content.

Many alloy white irons have been used for parts subject to wear by erosion or abrasion. Among recent applications may be mentioned coke crushers. For pins in crushers for pulverizing coal very good results have been obtained with a chill-cast cast iron (completely white).

Various considerations emphasize the need for a cast material which shall be machinable with a hardness approaching that of white irons. The authors have been induced to look for a grade of steel which would harden by oil or air-quenching, and would be easy to machine or to treat. The basic composition is: 0.6 to 0.8 carbon, 0.8 to 1.2 manganese, 0.25 to 0.50 silicon, 1.8 to 2.5 nickel, and 1.8 to 2.5% chromium. (Marcel Ballay & Raymond Chavy. *Foundry Trade J.*, Vol. 80, Sept. 19, 1946, pp. 55-61.)

Machining of Magnesium

Condensed from "Revue de l'Aluminium"

Magnesium and its alloys have extremely good machinability, which may compensate in some cases for their higher initial cost. Certain machining characteristics are the result of the inherent properties of magnesium: (1) The low density causes low inertia, even at high speeds. (2) There are no hard areas on the surface which might shorten tool life. (3) The high coefficient of expansion must be considered in precision machining. (4) Since the modulus of elasticity is five times less than that of steel, the bending of pieces mounted on centers will be that much greater. (5) In machining castings, one must guard against embedded steel particles and sand on the surface, as the friction developed between them and the tool might be sufficient to ignite very finely divided magnesium chips.

The factors which tend to increase the risk of ignition of magnesium are high cutting speeds, excessively small feeds, unsatisfactory tools, and poor machining techniques. Even with well-sharpened tools, feeds less than 0.001 in. and cutting speeds over 985 ft. per min. should not be used without lubrication.

Magnesium and its alloys are generally machined dry, but lubricants may be necessary to cool the piece being machined or to decrease the danger of ignition. Animal and vegetable oils which may oxidize and become acid are not recommended. Soluble oils, emulsions and all types of aqueous solutions are not used because the water would intensify any fire.

The good machinability of magnesium permits great latitude in the choice of cutting angles. However, particular attention ought to be given to the clearance and relief angles, the first to avoid rubbing of the sides of the tool on the piece being machined and the second to give the greatest possible leeway for the chips. Carbon steel may be used for finishing cuts. It is used mainly for taps, reamers and drills. However, high-speed steel is usually preferred for these tools. Other tools, such as turning tools and milling cutters, may be made of sintered carbide.

The long life of carbide tools gives very economical machining, particularly with high cutting speeds. Stellite type tools have a tool life intermediate between that of high-speed steel and carbide tools. Chromium plating and nitriding prolong the life of most high-speed steel tools in machining magnesium. The proper sharpening of all tools plays an important role, not only from the standpoint of cutting life but also from the point of view of surface finish. (*Revue de l'Aluminium*, Vol. 23, July-Aug. 1946, pp. 236-240.)

Glues for Use in Construction

Condensed from "Institut Technique du Batiment et des Travaux Publics"

During the recent war, great progress has been made in glues. It is believed that the glueing of all materials is now possible. In glueing, the two surfaces must be wettable, the glue must have an affinity for them and, generally, the glue film should be as thin as possible for rapid solvent evaporation.

The main classes of glues are: (1) glues of animal origin (bone, hide, casein and albumin), (2) glues of vegetable origin (starch), (3) cellulose glues (based on nitrocellulose), (4) thermoplastic resins (mainly polyvinyl acetate or butyral), (5) urea-formaldehyde glues of the thermohardening type (including urea glues for hot and cold glueing, re-inforced urea glues for use at high temperatures, and urea glues diluted with materials such as rye or corn flour to decrease their cost), (6) phenol-formol glues of the thermohardening type (high temperature glues, such as impregnated paper or tego film; dry powder to be suspended in liquids and alcoholic or aqueous solutions; the hardeners, generally basic, are separate), (7) melamine resin glues, and (8) the quite new resorcinol or formaldehyde glues.

The principle uses of these glues in construction are: (1) The manufacture of veneer panels, glued with casein or, preferably, a urea-formol glue. (2) The glueing of door and window assemblies. Although a large amount of joiner's animal glue is used, the shortage of this material has forced the substitution of chemical glues. (3) Mosaic wood flooring, where the type of joint varies with the constructor: bitumen emulsion, casein glue or better, latex or vinyl resin base emulsions. (4) The glueing of linoleum floors using vinyl resins or mixtures of vinyl and natural resins. (5) The construction of sound-proofing or insulation partition panels with clay base emulsions or bituminous emulsions which may also contain minerals, such as asbestos, in the case of insulation. (6) Molding, which is generally nailed and glued with joiner's animal glues. (7) Decorative motives made of a wide variety of materials and, consequently, a wide variety of glues. (8) Flocking of wallpaper with the use of thermoplastic glues. (Paul Baumgarten & M. Michoudet. *Institut Tech. Batiment Travaux Publics,* Circular Series H, No. 18, July 31, 1946, pp. 16-25.)

Notch Effects in High-Strength Aluminum Alloys

Condensed from "Journal of the Aeronautical Sciences"

A study was made of large-size structural members, aimed at obtaining parameters usable in design that would recognize the occurrence of some plastic flow in specimens with section discontinuities, and allow predictions of breaking strength to be made for a given material and "notch" configuration. An ideal stress notch insensitive material is defined in terms of a logarithmic relationship between notched ultimate stress and notch depth.

Several types of notched specimens were studied. These may be classified as internal and external notches. For the former, a drilled hole on the central axis of flat specimens was used. For the latter, 60-deg. V notches were made in three types: the symmetrical notch was put on round specimens; the pseudo-symmetrical notch was put on opposite surfaces of a flat specimen, the notches on the two surfaces being directly opposite each other; the asymmetrical notch was put on one surface only of a flat specimen. Root radius of the 60-deg. V notch was 0.02 in. in some tests and 0.002 in. in others. Two or more notch depths were used for each type of notch.

The tests were conducted on three grades of aluminum alloys, namely: 75ST, 14ST, and 24ST. Test specimens were prepared from extruded stock and from rolled stock. Test data indicate that the logarithmic relationship is a good first approximation and that a scale of stress notch sensitivity may be established. Alloy 75ST was shown to be more stress notch sensitive than 14ST, and alloy 24ST more sensitive than either.

It is recognized that the stress notch sensitivity indices presented are not to be taken as fully substantiated values. The logarithmic curves are in most cases drawn through two points that are not adequate to establish the curves. Furthermore, the curves are drawn as though all pass through the origin.

The reader is strongly cautioned regarding the application of the authors' major conclusion. That aluminum alloy 24ST or 75ST is more stress notch sensitive than alloy 14ST should not be construed to mean that the former alloys are less desirable for commercial applications than the latter. Rather, a recognition of this relationship permits design to compensate for a greater loss in strength at a region of section discontinuity while using an alloy for its otherwise desirable properties. (L. Schapiro & H. E. North. *J. Aeronautical Sciences,* Vol. 13, Aug. 1946, pp. 391-395.)

Metallic Coatings and the Superficial Protection of Castings

Condensed from "Fonderie"

Coating by immersion in molten metal, long known for tin and zinc, has recently been extended to aluminum. Tinning mild steel is easy but the graphite in cast iron interferes with the proper coverage. Various means of preparation have been proposed, but in spite of these precautions the results are often mediocre.

Some shops use intermediate coatings of iron, nickel or copper for cast iron. Zinc coating protects iron by its electrochemical action. Aluminum coating is not difficult if the mechanical properties of the coating are not important.

The Nineuil process consists of covering the article to be treated with a sort of paint composed of oxides of the metal or metals to be reduced and an organic binder. It is then heated in a hydrogen atmosphere at a temperature above the melting point of the coating metal. This process has been used for coatings, generally on steel, of copper, tin, bronze and cupro-nickel.

Hard surfacing with a welding torch or arc gives excellent adherence even of very thin coatings. Low melting point metals such as tin or lead may be deposited or hard, high melting point alloys of which there are many types. Alloys of Monel with silicon and tin have also been applied by this means.

Metal spraying is now applicable to almost any type of metal, although zinc is usually used for coating. The coatings are porous and may require some type of sealing for electropositive coatings. Adherence is very mediocre on polished surfaces but is satisfactory on a roughened surface. Metal spraying is used to repair small defects or porous areas in castings.

Electrolytic deposits are easily controlled. The porosity decreases as the thickness increases. Many inferior results have been due to insufficient thickness of the plate. One of the main applications of copper plating is for selective carburization. Tin plating requires less tin than a molten bath. Zinc and cadmium deposits, either bright or matte, are used for corrosion resistance. Nickel may be used for decorative or protective purposes but is usually covered with a thin chromium plate. The nickel plating of aluminum or zinc is more difficult than that of steel or copper alloys.

Various cementation processes are available. Nitriding of cast iron is more troublesome than that of steel because the graphite tends to embrittle the case. Sherardization (zinc), calorization (aluminum) and chromizing are other types of protective coatings applied by cementation methods.

Innumerable methods have been proposed for protecting metals by chemical means. Oxidizing (blueing) is frequently applied to steel. Replacement deposits formed by immersion in a solution containing a more electropositive metal may be adherent and convenient under certain conditions, for example in coating wire to be drawn. Phosphatizing gives excellent protection against corrosion or as a paint base. The MBV process is used to protect aluminum against corrosion. Protalization is somewhat similar in principle to phosphatizing and produces a layer of a fluor-oxide of titanium, chromium and aluminum on aluminum and its alloys. Chemical treatments appear to be most satisfactory for protecting magnesium although no means is completely satisfactory.

The anodic oxidation of aluminum gives better protection than the MBV process. The anodic coating protects against corrosion, acts as an insulator, and may be impregnated with dyes for decorative purposes. Aluminum castings to be coated

anodically should have a fine grain, as otherwise the appearance will not be pleasing. Since fissures and porosity in castings will retain some of the electrolytic solution, they should be immersed in a mild ammoniacal neutralizing bath after anodic treatment. (Marcel Ballay. *Fonderie,* No. 8, Aug.-Sept. 1946, pp. 285-299.)

Sub-Zero Treatment of High-Speed Steel

Condensed from "Metal Treatment"

Three high-speed steels, 18-4-1, 6-6, and 22-4-1 plus 10% cobalt were investigated with special reference to intermittent cutting.

The 18-4-1 high-speed steel was heated to 2372 F and quenched in oil. Tempering was done at 1076 F for 1 hr., while cold treatment was done at minus 105 F for 1 hr. Three tempering treatments, or a double temper with an intermediate sub-zero treatment, resulted in the same type of structure, that is most of the austenite had been converted to martensite in either case. It was further observed that the substitution of a sub-zero treatment for a tempering treatment resulted in a slightly lower hardness value.

Cutting tests were conducted with a shaper on "40" carbon steel and on nickel-chromium-molybdenum steel. These tests showed better results, that is more metal removed before tool failure, with the tools that had received three temper treatments than the tools that had been sub-zero treated between temper treatments.

The 6-6 high-speed steel was oil quenched from 2300 F. Tempering and cold treatment was done at the same temperatures and for the same length of time as above. The microstructure after tempering was the same whether a sub-zero treatment was used between temper treatments or not. A cold treatment between temper treatments again resulted in a slightly lower hardness value.

Intermittent cutting tests were conducted as above on the same kinds of steel. Results again indicated that more metal was removed before tool failure with a tool that had received three temper treatments than one that had received an intermediate sub-zero treatment.

Quenched from 2408 F in oil, the 22-4-1 plus 10% cobalt high-speed steel, given the same temper and sub-zero treatments, showed the same hardness relation as had the two previously tested steels. Cutting tests also showed the same result as with the other two steels tested.

While no beneficial effects are exerted on correctly heat-treated commercial high-speed steels by sub-zero treatments, it is possible that its application may be useful in certain high-speed steels with high carbon and/or vanadium contents. The austenite produced from these steels is very resistant to the martensite inversion at the tempering temperatures normally in use, but this austenite can be converted to a martensitic type of structure easily at temperatures in the region of minus 105 F. (K. J. B. Wolfe. *Metal Treatment,* Vol. 13, Summer 1946, pp. 79-94, 98.)

Symposium On Cutting Fluids

Condensed from "The Tool Engineer"

There are dozens of different types of cutting fluids, some designed for specific applications. The most are general in nature, but very many of your jobs require a rather special type of cutting fluid. Therefore, good practice requires that the cutting fluid be tested.

The conditions of the test should simulate actual working conditions in so far as possible; however, it is frequently desirable to increase the severity of the test by increasing cutting speed or by varying the shape of the cut in order to shorten the length of the test.

The machine for the test work should be able to operate under severe conditions of heavy cut and high speed. Tools should be mounted in heavy holders so that no chatter is present during any test. Chatter due to insufficient rigidity of the work, tool, or machine will give erratic results.

With a given cutting fluid, or when cutting dry, to obtain the tool life of single point, high-speed steel tools, it is desirable to run several tools to destruction at different speeds so as to obtain a curve of cutting speed versus tool life. Such a curve, when drawn on log-graph paper, will be a straight line. It is relatively easy to determine whether or not uniform results are being obtained by the nearness of the points to a straight line. If the points do not fall close to a straight line, it is usually an indication that the material being machined is not of uniform machinability, that tool material or shape is not uniform, or that the speed has not been held constant.

To obtain the tool life, cutting speed curve for a given cutting fluid (or under dry cutting), the first tool should be run at relatively high speeds to give a tool life of approximately 1½ to 2 min. Tool life is timed by stop watch from the moment the cut begins until final failure.

Difficulty is often encountered in getting points that fall on—or close to—a straight line. When such a condition occurs, it is necessary to consider, first, the accuracy with which tools have been ground and the uniformity of the tool material; second, to investigate the work material which, obviously, must be of uniform structure throughout and free from slag inclusions.

In any cutting fluid test, the temperature of the cutting fluid should be held fairly constant. In most of our test work we hold cutting fluid at 100 F to plus 5 F. (D. J. Wangelin. *Tool Engineer,* Vol. 16, July 1946, pp. 18-23.)

Titanium and Zirconium— Two Metals of the Future

Condensed from "Metal Industry"

Titanium and zirconium are far from rare metals, as their occurrence in the earth is greater than that of some of the so-called common metals. The chief reason most metallurgists have not attempted to use them is that they have not realized that both are malleable and ductile in the pure state. Previous work had shown quite definitely that their brittleness was caused primarily by oxygen and nitrogen rather than by metallic impurities. Recent laboratory developments have indicated the way for their production on a comparatively large scale.

The present method for producing titanium is based on Kroll's procedure of reducing pure titanium chloride with magnesium in an argon or helium atmosphere. Pure titanium chloride, made by chlorination of titanium oxide mixed with carbon, is dripped onto molten magnesium under a helium atmosphere. The mixture of titanium, magnesium chloride and magnesium thus obtained is wet ground, screened and leached with dilute hydrochloric acid.

The resulting powder is pressed into briquettes and sintered at 1830 F under a high vacuum to remove the hydrogen picked up during leaching. The sintered material can be rolled at room temperature with reductions of as much as 20% before annealing or at 1200 F with reductions as great as 75%. The Bureau of Mines simplified reduction furnace will produce as much as 120 lb. titanium per run.

The preparation of ductile zirconium is more difficult than that of titanium. Zirconium chloride is made from zircon with the intermediate step of zirconium carbide. The zirconium chloride is volatilized and the vapors permitted to come in contact with molten magnesium in a helium atmosphere. The magnesium chloride and magnesium are subsequently distilled from the zirconium at about 1650 F under a high vacuum. The residual zirconium metal can be remelted in a vacuum arc furnace. The ingots can be hot rolled into sheet and are readily machined, forged or swaged. A 40-lb. furnace is under construction.

Except for melting point and density, zirconium has much the same properties as tantalum. The corrosion resistance is about the same, except that zirconium has greater resistance to alkalis. The tensile strength is similar, but the elongation and modulus of elasticity of the zirconium are less. It also work hardens more than tantalum, which makes it more difficult to form, but the final product is stiffer. The density is less than half that of tantalum.

Because the great potential supply of zirconium will make it possible to produce it for much less than the present price of tantalum, it would appear that zirconium will replace tantalum for many uses, such as radio valves, rectifiers, electrolytic condensers and parts in contact with acids. Particular mention should be made of the excellent ability of zirconium as a getter in radio tubes.

Titanium should not be considered as a competitor to tantalum, but as a light metal with exceptional chemical and physical properties. On a strength-weight basis, pure titanium is preferable to other pure

(Continued on page 130)

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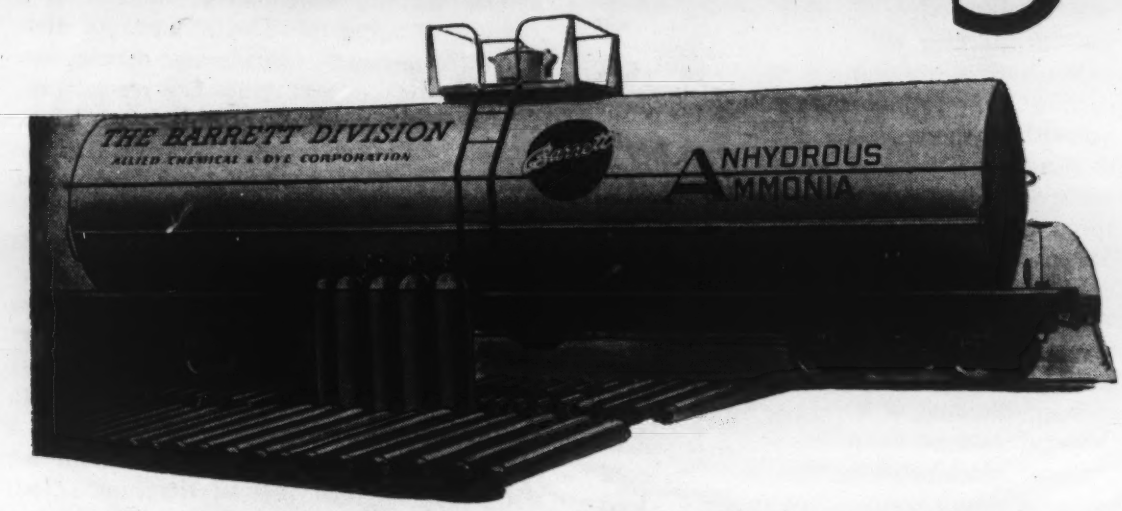

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DIGEST

metals such as aluminum and magnesium, and compares favorably with their alloys and 18:8 stainless steel. There are possibilities that alloying elements will greatly improve the properties of titanium. The great use of titanium probably will be in the light metal field for apparatus in which corrosion resistance is desired. (W. J. Kroll & A. W. Schlechten. *Metal Ind.*, Vol. 69, Oct. 18, 1946, pp. 319-322.)

Fiberglas-Reinforced Plastics as an Engineering Material

Condensed from a Paper of the American Society of Body Engineers

Fiberglas-reinforced plastics are a relatively new engineering material with a combination of properties which entitles them to consideration for many applications, and particularly for the construction of bodies of all types of automotive vehicles.

The combination of glass fibers with resins provides a material that will not corrode and that possesses a higher strength-weight ratio than the structural metals. The use of glass fibers in plastic products reduces the absorption of moisture normally present in the natural or synthetic fibers which compose plastics; this increases the dimensional stability of the material.

The ability to achieve directional properties is a great advantage in design. If stresses to which the product will be subjected will occur in several directions, it is possible to distribute the glass fibers in these directions, in proportion to the amount of stress in each direction. Or, if the principal stress is to come from one direction, it is possible, by arranging the glass fibers in the direction of stress, to attain maximum strength in that direction.

Fiberglas-plastic laminates have good dielectric strength. They have no definite yield point, so it is possible to work the material very close to its ultimate strength without permanent deformation. The same characteristic prevents the material from denting when struck a sharp blow. Because of its fibrous structure, and the consequent scattered distribution of any imperfections, the material will not propagate cracks.

The construction of prototypes of automobiles is one of the two fields in which it is believed Fiberglas-reinforced plastics are now qualified for use. The other is for the construction of certain body parts such as trunk lids, bumpers, and heat and acoustical insulation. Fiberglas baths and blankets are now used as heat insulation in refrigerated trucks and trailers. Work is now progressing on a board form for the dash board and on the use of coated Fiberglas fabric in fender wells.

DIGEST

In employing Fiberglas-plastics for body parts, higher material costs must be offset by efficient design requiring a minimum amount of material, reduced tooling costs, reduced assembly costs, and corollary savings such as elimination of counter-weights. (Games Slayter. Paper, *Am. Soc. Body Engineers*, Oct. 25, 1946, 14 pp.)

Electro-Galvanizing

Condensed from "Metal Industry"

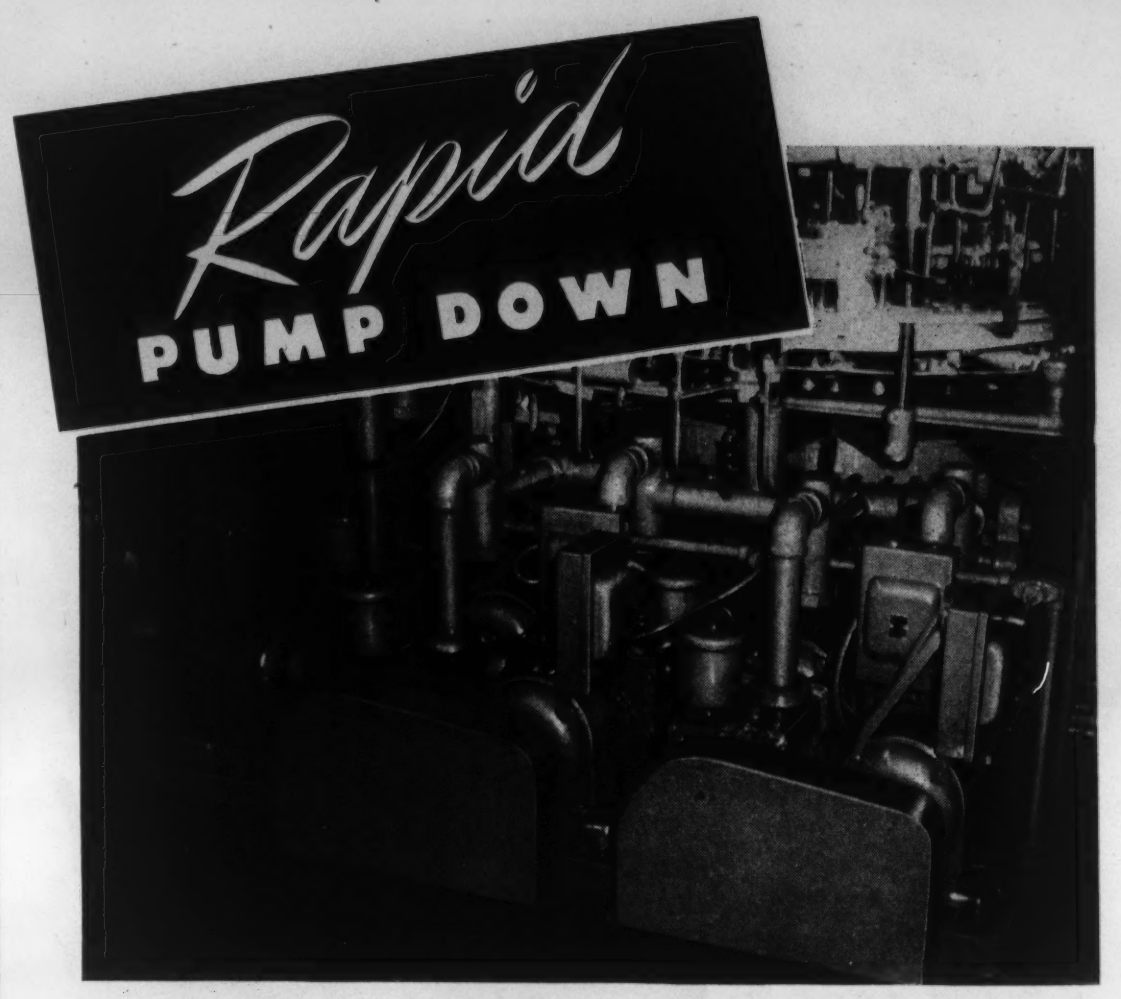
The Tainton electro-galvanizing process is an adaptation of the Tainton high acid-high current density process for making electrolytic zinc, in which an electrolyte is made up from roasted zinc ore and sulfuric acid. After purification, the zinc sulfate solution is electrolyzed using insoluble anodes; thus, as zinc is deposited at the cathodes, strong new solution must be fed into the cells and spent solution is withdrawn to be brought up to strength again with roasted zinc ore.

The Tainton electro-galvanizing process offers these features: (1) High purity coating, giving superior resistance to corrosion; (2) ductile coating which withstands severe deformation; (3) perfect bonding to steel wire: no peeling; (4) concentricity of coating around wire; (5) uniformity of weight; (6) rapid deposition; and (7) physical tests of high carbon-high tensile steel wires are not impaired by treatment.

Although hot dip galvanizing produced galvanized wire of a high quality, the product had the defects which are inherent in all hot dip methods. It is impossible to produce steel wire, carrying a pure zinc coat by passing it through a bath of molten zinc, because zinc and iron have such an affinity for each other at temperatures required for hot galvanizing that a zinc iron alloy is immediately formed.

The Brylanizing process, which has been developed to replace the hot dip, can best be considered as a unit producing electrolytic zinc of 99.9+% purity which is deposited directly on to travelling wire cathodes, instead of on to stationary aluminum cathodes as is the case at the electrolytic zinc production plants.

Bright drawn wire for plating is annealed, cleaned, plated, washed, dried and polished in the one operation. The factors influencing the plating of steel with a smooth ductile deposit of pure zinc may be tabulated as follows: (1) high and uniform cathode current density; (2) concentration of zinc and acid in the plating solution; (3) temperature of the electrolyte; (4) circulation of the electrolyte; and (5) purity of the electrolyte.



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DIGEST

All these factors are concerned with the maintenance of a high hydrogen overvoltage at the cathode surface, and their control is particularly important at the point where the wire is first struck with zinc. (H. Roebuck & A. Brierley. *Metal Industry*, Vol. 69, July 19, 1946, pp. 50-53.)

New Tin-Zinc Coatings Protect Steel From Rusting

Condensed from "Tin and Its Uses"

A new group of alloy coatings has recently been devised to protect steel from rusting. The two compositions which appear to have the most advantages are one having about 80/20 tin-zinc and another having about 50/50 tin-zinc.

The 80/20 alloy has been tried out as a finish for the steel chassis of radio sets, where it has proved to have outstanding resistance to "tropical" conditions. Where the protective coating must withstand mechanical damage the 50/50 alloy is preferable. Specimens heavily scratched and showing considerable areas of bare steel have been exposd to severe corrosion conditions without any formation of rust. Both alloys are readily solderable.

In salt spray tests these tin-zinc alloys have withstood corrosive attacks better than tin and zinc and cadmium used alone. Cadmium puts up an excellent performance against humidity, but breaks down rapidly under attack of salt spray.

These tin-zinc coatings have also been deformed in the Erichsen Cupping Machine without damage to the coatings, while tin and cadmium coatings have been damaged and showed rusting.

The use of these new alloy coatings for radio chassis and for parts of electrical instruments is already established. They may also offer a convenient foundation for nickel-chromium plating where high temperatures are not involved, as for instance, on automobile trim and the like. They have many points of superiority to the existing copper flash; they are white in color, will protect the steel sacrificially, and are easily polished.

Articles of domestic hardware, flyscreen, rabbit wire, fencing, and electric power line hardware would all be worth giving the extra protection and longer life that these new coatings provide. It is also possible that many applications will be found on yachts and sea-going ships of all sizes, as these alloys are outstandingly resistant to marine conditions. Perhaps even corrugated iron sheeting for more exacting purposes will also be given a very greatly increased span of useful life by the adoption of tin-zinc alloy coatings. (*Tin and Its Uses*, Vol. 17, Oct. 1946, pp. 5, 14.)

SHOP NOTES

Increasing the Life of Machine Tool Parts

by E. W. Nelson,
Denham & Co.

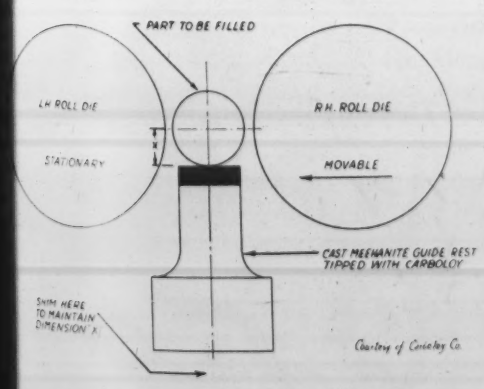
Often cemented carbide can be used to advantage in critical spots on machine tools where excessive wear is usually encountered. Recently a New England machine tool builder reported rapid wear on the cast iron guide-rest in a circular die roll threader. The wear was caused by the rotation of the SAE 4140 steel blanks during the roll threading operation and was so severe that the guide-rest had to be re-ground to the required flatness after each lot of 9,000 pieces.

The operation consisted of rolling a 7/16-in. — 20 — Class 3 thread — 5/8-in. long on the SAE 4140 stock. Following each re-grind, the guide-rest had to be shimmed up in order to maintain the required height from the top of the guide-rest to the centerline of the part being roll threaded. After several re-grinds, the height of the accumulated shims made the guide-rest so unstable that a new guide rest had to be installed.

A contributing factor encountered was that a scored surface occasionally occurred on the top of the threads. This was reproduced on the iron guide-rest. Each time this happened, a re-grind was necessary to remove the objectionable marks from the surface of the guide-rest.

In an effort to eliminate excessive re-grinding and setup time, the guide-rest was tipped with cemented carbide, as shown in the accompanying sketch. Production between re-grinds rose from the former average of 9,000 pieces to an average of 74,000 pieces. Moreover, each re-grind of the guide-rest required the removal of only 0.001 in. of carbide metal, thereby greatly simplifying the re-adjustment of the rest.

The problem of marring of the guide-rest surface by scored threads was eliminated, the carbide guide-rest surface being so hard that scored surfaces of threads were not reproduced on it.



Sketch shows how a cast iron guide-rest was tipped with cemented carbide to improve its wear resistance.

How to Pour Bearings

by K. T. MacGill,
Joseph T. Ryerson & Son, Inc.

Fundamental in the making of good bearings is the selection of an alloy having the proper physical properties, hardness and compressive strength, freedom from segregation, and good grain structure. Aside from the fact that the selection of such an alloy is a necessity in order to secure dependable, long life bearings, the procedure followed in casting is also tremendously important if good bearings are to result. Even the best babbitt can fail in service if a few fundamental pouring rules are not followed.

There are many ways in which bearings can be poured, with assurance of equally good results. However, experience has proved that if the basic principles of heat transfer from molten metal through the bearing shell are observed, good bearings with lining tight against the shell should be obtained, regardless of the particular set-up or method that is followed. The average plant or shop usually has or can readily devise the equipment and fixtures that are required. From this point on, it is only necessary to follow a few, simple, fundamental rules.

It pays to always use new babbitt, made of virgin metals. When you have decided upon the proper grade for the service involved, do not mix with reclaimed or scrap metal of unknown analysis. While it might appear that re-using old metal is one way to save on bearing costs, it is seldom wise to try and economize by mixing used metal with new. Too often dirt or other harmful foreign matter will be included, or metals of unlike analysis may not produce the dense, close grained structure required successfully to resist wear. If a sizable quantity of old metal is accumulated, this can be used for pouring secondary bearings where loads are light and the performance required is less exacting.

Using a wire brush, clean all equipment, fixtures and the inside of the shell thoroughly. Follow this with a blowtorch and further brushing if necessary. The blowtorch also serves to drive out all moisture from the bearing shell, which is important. The mandrel should be as

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thin walled as possible, with ends closed with wood plugs to prevent heat loss.

Put a waste head on top of the shell. This takes care of the problem of shrinkage as the bearing solidifies, assuring sufficient metal to completely fill the bearing area. The waste head is made of a putty-like substance that is especially prepared for the purpose, and as it does not dry out, it can be used over and over again. The height of the waste head depends upon the size of the bearing, larger bearings requiring more excess metal at the top to make up for shrinkage.

Before you start to melt, make sure that you have sufficient babbitt to pour the entire bearing at one time. This is necessary in order to secure a dense and completely uniform structure. The melting pot should be placed close to the work. This will prevent heat loss in ladle as the molten metal is transferred from the pot to the bearing fixture.

Follow the manufacturer's recommendation for correct pouring temperature. Generally speaking, a temperature of from 850 to 950 F is sufficient. After the babbitt is completely molten, the best pouring temperature is related to the thickness and size of the bearing being poured. The metal should pour almost like water. Heating to a slight excess is not harmful, the only disadvantage being the accumulation of a higher percentage of dross resulting from oxidation.

Thick, heavy bearings can be successfully poured at a lower temperature than bearings that are long and thin. The metal must be hot enough to reach the bottom of the mold and start to build up before any sign of setting occurs. One simple method of checking to determine if the metal has reached the correct pouring temperature is to insert a small, dry pine stick in the pot. It should burst into flame immediately upon contact with the hot babbitt.

Before starting the pouring operation, warm the bearing shell to a temperature of about 200 F. As previously stated, this serves to drive out all moisture and also prevents too quick or non-uniform solidification of the molten metal.

Fill the space completely and as rapidly as possible, continuing pouring until the top of the waste head is reached. Cool the bearing shell by applying water or wet rags, starting at the bottom and working slowly upward. By thus drawing the heat outward, the metal starts to solidify at the inside surface of the shell, adhering tightly to the wall. As the babbitt sets and contracts in this area, the void is filled with hot metal from the mandrel side, which in turn is fed from the surplus metal provided by the waste head at the top of the shell.

When the metal has completely cooled and set, if the bearing has been properly poured, the mandrel should not stick but should free itself from the fixture with little effort.

While conditions and facilities will vary from shop to shop, nevertheless if the foregoing simple, basic rules are followed there is no reason why every bearing produced should not be sound, dependable and capable of giving the long, trouble free service that is expected of it.

SOLDERING FIXTURE AIDS JOINING OF SMALL PARTS

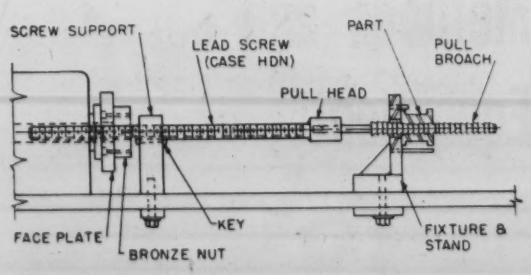
A fixture incorporating two carbon electrodes mounted in a Micarta panel has aided in the soldering of small parts by electric heat at the Mansfield, Ohio plant of Westinghouse Electric Corp. The electrodes are mounted at an angle so that they can be bridged by small parts, such as the copper strap terminal shown in the picture. When current flows through the terminal, it is heated to the proper soldering temperature and solder is applied. A rheostat mounted under the bench regulates the amount of current used.

The Lathe Used as a Broaching Machine

by Bernard E. Frank

Small companies with limited equipment and capital quite often must rely upon their ingenuity to adapt their existing machine tool equipment to fit new jobs. A typical example of this occurred in a shop which received an order for parts to be made in the shape of a bushing. The hole had to be broached accurately and there were only a few days to meet the delivery schedule. The only broaching machine available could not be spared. The arbor presses were not strong enough, and slow and tiring to operate.

How was the problem to be solved? The only thing left was to build a broaching machine. This was done in 16 hr. A lathe was available with the spindle mounted on tapered roller bearings, so it could withstand quite a heavy side thrust. Further, there was a spare leadscrew with acme thread and keyway all ready to use except for case hardening. A bronze nut was attached to the front of the face plate of the lathe. (See sketch.) In front of this, a support was attached to the bed; the support held a key to keep the screw from turning with the spindle. At the other end of the bed a stand was bolted to serve as a fixture for holding the part and the broach. At the end of the screw was fastened a suitable pull head.

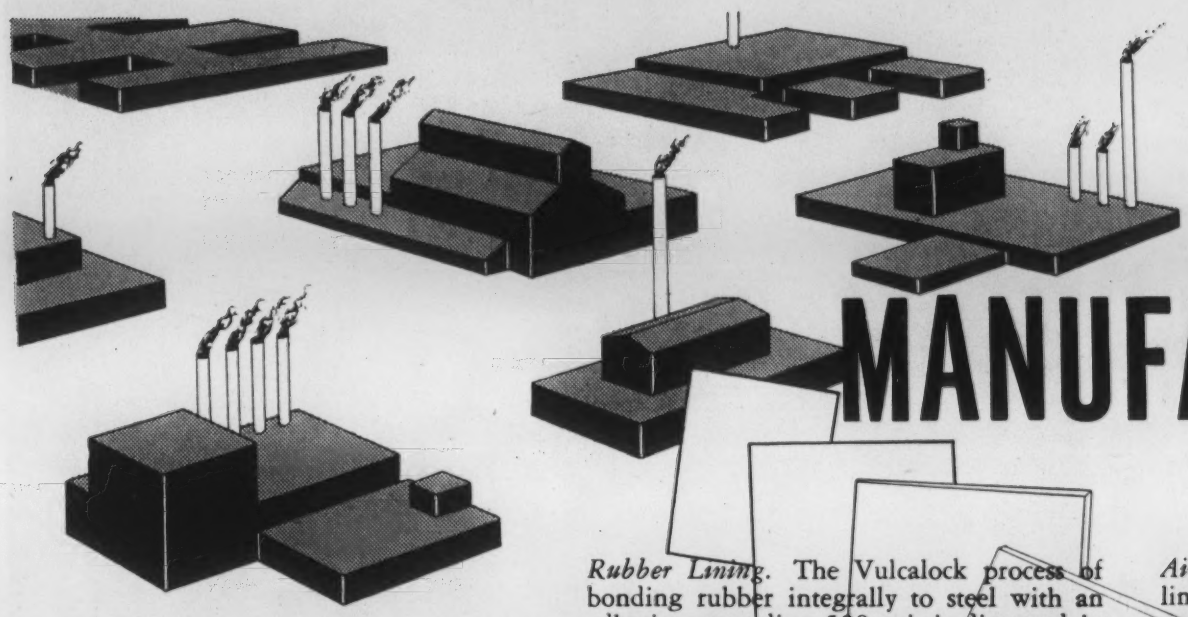


Drawing shows how a lathe can be adapted for broaching operations.

By rotating the spindle clock-wise in low gear, in this particular case, the screw moved to the left and pulled the broach through the hole of the part; by reversing the motor the screw moved in the opposite direction, or back to the loading position.

Basically that was the setup; later on, refinements, such as an automatic release of the broach and stops to limit the movement of the screw, were added.

To conclude, it is a well known fact that the lathe is one of the most versatile machine tools in the shop. Other than turning, many operations can be performed on it, such as milling and grinding. Thus, with this equipment you can do a broaching operation efficiently.



MANUFACTURERS

Materials

Laminating Resin. This 4-page bulletin of *American Cyanamid Co.* discusses Laminac resin, a polyester resin for sealing microporous flaws in castings, as well as providing a surface film that prevents steam corrosion. Schematic drawings are included. (1)

Steel Pipe. The historical background and modern uses of steel pipe in large buildings, process industries, homes, etc., are interestingly presented in a 48-page, illustrated catalog published by *the American Iron & Steel Institute.* (2)

Manganese Steel. The many facilities, applications and advantages of using manganese steel for cement mill equipment are discussed in a 36-page, illustrated bulletin, No. 1043-CM, of *American Manganese Steel Div., Am. Brake Shoe Co.* (3)

Copper Products. Complete data on a variety of copper wirebars, billets, cakes, ingots, etc., including specifications, physical defects and resistivity, are presented in a 26-page, illustrated catalog issued by the *American Metal Co., Ltd.* (4)

Weldability of Copper-Base Alloys. A comprehensive compilation of welding and composition information relating to 313 copper-base alloys is presented in a list that also includes manufacturers, their trade names, preferred welding process, etc. This bulletin, No. D-2383, is offered by *Ampco Metal, Inc.* (5)

Molding with Thermoplastics. This attractive, 108-page catalog distributed by *Celanese Plastics Corp.* presents complete data on the injection and extrusion molding of various types of Lumarith (Celanese plastics). Specifications and conversion tables are included. (6)

Ceramics. Standards, design criteria, body characteristics, and shapes and sizes of ceramic insulating materials are all contained in a 28-page, illustrated bulletin, No. 720, of *Centralab Div., Globe-Union, Inc.* (7)

Rubber Lining. The Vulcalock process of bonding rubber integrally to steel with an adhesion exceeding 500 psi. is discussed in a 4-page catalog section, No. 9000, issued by *B. F. Goodrich Co.* (8)

Adhesives, Plastics, Etc. A complete line of the products manufactured by the *Hercules Powder Co.,* including a variety of adhesives, plastics, packaging, rubber, lubricants, synthetic resins, etc., is presented in a 40-page, illustrated catalog. (9)

Metals and Alloys. A complete line of nonferrous metals and alloys produced by *P. R. Mallory & Co., Inc.* is presented in a 16-page, illustrated bulletin. Properties and various applications are included. (10)

Acrylic Plastics. Typical applications and many advantages of using Plexiglas, acrylic resin thermoplastic sheets and molding powders, are presented in an 8-page, illustrated bulletin offered by *Rohm & Haas Co.* (11)

Flame Cut Shapes. The many facilities of *Jos. T. Ryerson & Son, Inc.* for producing plain and intricate shapes from steel plates by flame cutting are discussed in a 4-page, illustrated bulletin. (12)

Thermocouple Lead Wires. A chart recommending the type of thermocouple and extension lead wire to use with all pyrometers and thermocouples in aircraft, engines and industrial plants is included in a 4-page, illustrated bulletin, No. 30, offered by *Thermo Electric Co.* (13)

Nonferrous Castings. A variety of castings made from Hecla Bronze, Everdur and aluminum and its alloys are described and illustrated in an 8-page bulletin published by *Thomas Paulson & Son, Inc.* (14)

Protective Synthetic Coating. Properties, application data and typical uses of Ucilon, a protective synthetic coating that resists acids, alkalies, salts, cleaning compounds, etc., are discussed in a 4-page, illustrated bulletin offered by *United Chromium, Inc.* (15)

Methods and Equipment

Welding and Cutting Equipment. A new, 64-page, illustrated catalog published by *Air Reduction Sales Co.* contains a complete line of oxyacetylene welding and cutting gases and equipment, and arc welding machines, accessories and electrodes. Prices are included. (16)

Induction Furnaces. This 8-page illustrated bulletin, No. 12-A, offered by *Ajax Electrothermic Corp.,* describes 3- and 6-kw. spark-gap converters for induction heating, brazing, hardening and melting applications. Specifications and performance data are included. (17)

Wheel and Tool Dressing Fixture. This 4-page, illustrated bulletin of *Allied Machinists of Waltham* describes Gem-Flex, a wheel and tool dressing fixture for machine shop work. Price is included. (18)

A.C. Welder. Bulletin No. 12-B6241B, four pages, features the Ampac "200", an alternating current welder produced by *Allis-Chalmers Mfg. Co.* that uses less power, has no arc blow, etc. Specifications and illustrations are included. (19)

Low-Temperature Welding. The advantages of using low temperature for welding, as well as a complete list of products produced by *All-State Welding Alloys Co., Inc.,* are presented in a 32-page booklet. (20)

Metal Cleaner and Conditioner. Technical Service Data Sheet No. 3-2-210, four pages, discusses Diridine, a modern metal cleaner and conditioner that simultaneously cleans and phosphate coats metal surfaces for painting. Typical applications are illustrated in this bulletin, offered by *American Chemical Paint Co.* (21)

Hardness Tester. A portable hardness tester for rounds and flats up to 1 in., and its accessories, is described and illustrated in a 4-page bulletin offered by *Ames Precision Machine Works.* Prices are included. (22)

Cutting Stainless and Nonferrous Metals. The Oxyarc process and Oxycuttend rod for hand cutting or piercing stainless and alloy steels and nonferrous metals is discussed in a 4-page, illustrated bulletin of *Arcos Corp.* (23)

Altitude Units. Two types of altitude units that cover a wide range of vacuum requirements are described in a 4-page, illustrated bulletin of *Bowser, Inc.* Specifications and a chart of altitude-pressure-temperature curves are included. (24)

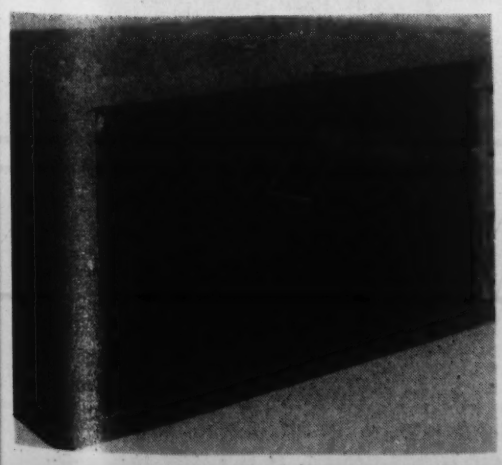
Potentiometers. A complete line of Electronik strip chart potentiometers, operating on the electronic "Continuous Balance" principle, is described and illustrated in a 24-page bulletin, No. 15-10, published by *Brown Instrument Co.* A control forms

New Materials and Equipment

Quality Control Instrument Detects Flaws in Wire and Thin Materials

A new flaw detector which can continuously detect and count holes, weak spots, and conducting paths in thin materials such as paper, sheet rubber, sheet mica, varnished cloth, plastic materials and enamel films on wire during the manufacturing process has been announced by the *Special Products Div., General Electric Co.,* Schenectady, N. Y.

The new instrument permits quality standards to be set up close to the point of manufacture so that variations in quality can be quickly detected and correcting adjustments made with a minimum of waste. Applications include detecting places of low dielectric strength in insulating materials, and holes in materials which must resist the passage of light or air.



Electrode unit of the G.E. flaw detector showing two types of electrodes.

The new flaw detector can be applied to sheet materials up to 0.025-in. thick moving as fast as 450 ft. per min. and to wire moving up to 100 ft. per min. It consists of an electrode assembly through which an adjustable voltage is applied to the material undergoing test, and an electronic circuit which indicates the flow of current through the material which occurs when a flaw passes under the electrode. Electrodes have been especially designed for use with specific materials.

The flaw detector can be made to sound an alarm, operate a recorder, or shut down the manufacturing process when flaws are encountered, and can be arranged to indicate when flaws exceed a given total. The control unit may be mounted remotely, where an operator can read the counter or watch for flashes of a flaw-indicating red light.

New Flash Welding Equipment Incorporates Design Changes

A new line of flash-welding equipment has been announced by *Sciaky Bros.,* 4915 W. 67th St., Chicago. The welders range in size from 75-kva for 0.90 sq. in. mild steel up to large, completely automatic machines rated 500-kva for capacities up to 5 sq. in. Included are mitre joint welders for production of steel and aluminum window frames, door sash, etc., for the building trades.

Flashing and upsetting on the smaller welders is by means of a hand lever. Large welders may be either all power-operated, or a combination of hand lever flashing and power upsetting.

Several design features are incorporated in the line. Frames are designed as a self-contained beam with conductors from transformer to dies outside the frame. This eliminates need for a weakening cutout within the frame and allows transformer to be protected from flash sparks. Platens move on a wide, rigid T-shaped bed with a narrow guiding key. Clamps are actuated by a high-pressure, booster-supplied hydraulic system. This allows the use of small diameter cylinders so that the direction of force can be directly over the clamps.

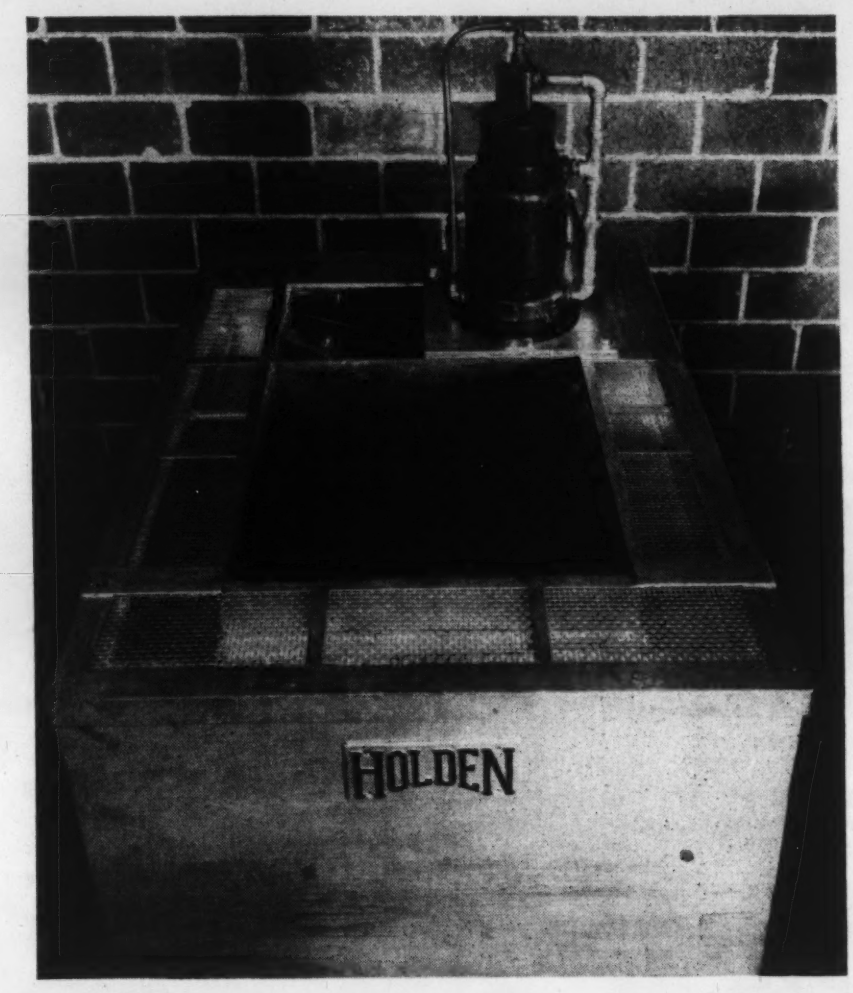
On the large power-operated machines, flashing and upsetting is independently controlled. Both platens are moved by an air cylinder driving a wedge-shaped cam between rollers.

When welding tubes over 3-in. O.D., a dual transformer supplies heat to both upper and lower dies, assuring perfect distribution of heat. Heavy duty machines can be equipped with synchronous timing control, post-heat current and phase shift heat control to permit welding of aluminum alloys, high carbon and aircraft steels.

● The *Hanson-Van Winkle-Munning Co.,* Matawan, N. J., has announced a new grain cement and thinner, which is an improved adhesive for polishing wheels that overcomes the deficiencies of organic glues.

Salt Bath Furnace Designed for Interrupted Quenching

A new furnace for use in austempering and martempering has been developed by the *A. F. Holden Co.*, New Haven 8, Conn. It can also be used for hot quenching stainless steels, tempering operations to 700 F, bright tempering, and age hardening aluminum alloys. The normal operating range is 350 to 750 F.



This new salt bath has been designed specially for interrupted quenching processes.

The furnace can be heated by any of three methods: immersed electrodes, resistance units, or under-fired gas burners. Forced circulation is provided by a motorized pump which circulates the liquid every 3½ min. Cooling is accomplished by pumping into troughs and back over a spillway into the pumping section. Additional cooling is obtained by blowing air at 16-oz. pressure for any volume under the spillway. The unit has automatic control of temperature both in the quenching area and cooling area.

Since there is bound to be contamination of the salt bath as a result of quenching from high temperatures, a screen or filter type of receptacle is located at the top of the spillway. This screen helps to take out any of the metallic particles and salt sludge.

A basket is also located in the quenching zone which acts as a receptacle to catch lost parts or sludge from the high temperature baths.

The productive capacity of the furnace, having inside pot dimensions 36 in. long by 26 in. wide by 40 in. deep, is 500 to 700 lb. of work per hr. quenched from the hardening temperature range to a temperature of 400 F.

Finishing and Deburring Machine Designed for Very Small Parts

A new small-sized machine for deburring small parts has been announced by the *Sturgis Products Co.*, Sturgis, Mich.

Cylinders of the new machine are 8 in. wide, 12 in. across the flats. It has a variable drive of 35 to 70 rpm. The flats are lined with kiln dried hard maple, and ends are rubber sealed. The cover is secured to the cylinder and the cylinder is mounted on the machine by ingenious lock and an adjustable clamp that permits quick loading and unloading. The machine can be supplied without base for bench mounting.

Installations where the equipment are most suitable are small plating shops; manufacturing plants with small finishing departments; and those plants engaged in furnishing only very small parts.

All mechanical finishing operations may be performed in the equipment including grinding, deburring, polishing, britehoning and coloring. The controlled rotary action of the wet mixture of Midget chips and compound produces a surface suitable for plating by uniformly removing burrs, sharp edges and corners on small stampings, machined parts and die castings.

Non-Synchronous Resistance Welding Controls Have Advantage of High Speed

A new line of non-synchronous electronic resistance welding control combinations has been announced by the *Control Div., General Electric Co.*, Schenectady 5, N. Y. The new line, designed to meet the new NEMA standards for resistance welding controls, includes combinations of ignitron contactors and sequence-weld timers, with or without electronic heat control, mounted in a single cabinet.

Although designed for mounting on the right-hand side of the welding machine, the control cabinet can be placed on the floor alongside the machine or mounted on a wall or balcony. When mounted on the welder it is necessary only to connect air, water and power for a complete installation, as all inter-connections between individual controls are made at the factory. By adding extension cable the control station may be mounted at the machine while the main control panel is remotely located.

The individual panels in the new combination are of the same design as those now in use. The ignitron contactors offer high-speed operation and flexibility. The sequence-weld timers give accuracy of timing regardless of normal time voltage variations, because voltage-regulation tubes are used in the timing circuit. Electronic heat control is provided for stepless adjustment of welding current.

Glass-Silicone Laminates Developed for Many Uses

Several new glass-base laminates having many possible applications are now being produced by the *Formica Insulation Co.*, Cincinnati 32, Ohio.

One of these is a glass-silicone laminate having qualities and characteristics for electrical insulation applications. This plastic laminate is made from staple-fiber glass fabric plus a silicone resin. It is heat resistant and tests of motors insulated with this material have shown it to withstand temperatures of 482 F. It also has an arc resistance value of 265 sec.

Another material recently reported is a chemical grade of silicone-glass insulation that is acid-resistant. It was primarily developed for use in connection with wet-cell storage batteries.

Another material, a cotton-base-melamine laminate, is adaptable to requirements of electronic design. It is easily machined, has good strength, high insulation resistance, and arc resistance.

Low Cost Temperature Controller Has Simplicity with High Sensitivity

For temperature control of ovens, baths, presses and coolants where indicating or recording is not required, *Leeds & Northrup Co.*, 4934 Stenton Ave., Philadelphia 44, has introduced a new low cost temperature controller. Although the instrument signals and controls only, temperature readings can be taken manually.

The instrument consists of a Wheatstone bridge circuit with a vacuum-tube amplifier as the detector. Vacuum tubes are standard types. It is completely a.c. operated.

The temperature-sensitive elements used are "Thermohms", resistance thermometer bulbs. Since the length of leadwires does not affect calibration, location of the temperature sensitive elements can be changed whenever desired.

Surface Treatment of Aluminum Gives Bright Finishes

The *Technical Processes Div.* of the *Colonial Alloys Co.*, Philadelphia 29, reports an electrolytic process for coloring aluminum and its alloys. Finishes resembling brass and chromium can be obtained; also reflective mirror effects and simulated gold, silver and blue, black, green, red, pastels and matched shades are possible. Surfaces may be treated to resist atmospheric and other corrosive conditions.

The finish is not an applied coating but is part of the surface of the aluminum which has been electro-chemically changed to produce the result. The surfaces are maintained by washing now and then with a mild soap solution.

The common aluminum alloys such as 2S, 3S, 52S, 53S, 56S, Alclad and Pureclad respond to this treatment. They should, however, be free of scratches, draw and roll marks, or these will appear in the final finish. A pre-finish equivalent to a 200 mesh (or finer) treatment gives uniform reflective surfaces after treatment.

New Milling Machine Features Electronic Control and Universal Head

A universal head milling and die sinking machine for toolroom work, and especially for making die casting dies, forge dies, jigs and fixtures, is available from *Reed-Prentice Corp.*, Worcester 4, Mass. Its design, including universal head, centralized control panel, infinitely variable feeds and spindle speeds, suit it for die sinking, duplicating, boring, drilling and face or straddle milling.

The milling and boring head, of the Quill type, is mounted on a sliding ram and can be adjusted for all angles up to 45 deg. front to back and 30 deg. left to right. It can also be depressed to horizontal position for milling with an arbor. Infinite variable spindle speeds from 90 to 2200 r.p.m. are obtained through a Reeves drive and one back gear. It has an infinite feed rate from ⅛ to 16 in. per min.

The table, of ribbed construction, is 46 in. long and 12 in. wide. Automatic adjustable feed stops for table, cross saddle and vertical saddle are provided.

Maximum vertical distance from table to face of spindle is 18 in. Maximum distance from spindle to column is 26 in. and the minimum distance is 12 in. The spindle drive requires a 3-hp., a.c. motor and the feed drive a 1-hp., d.c. motor.

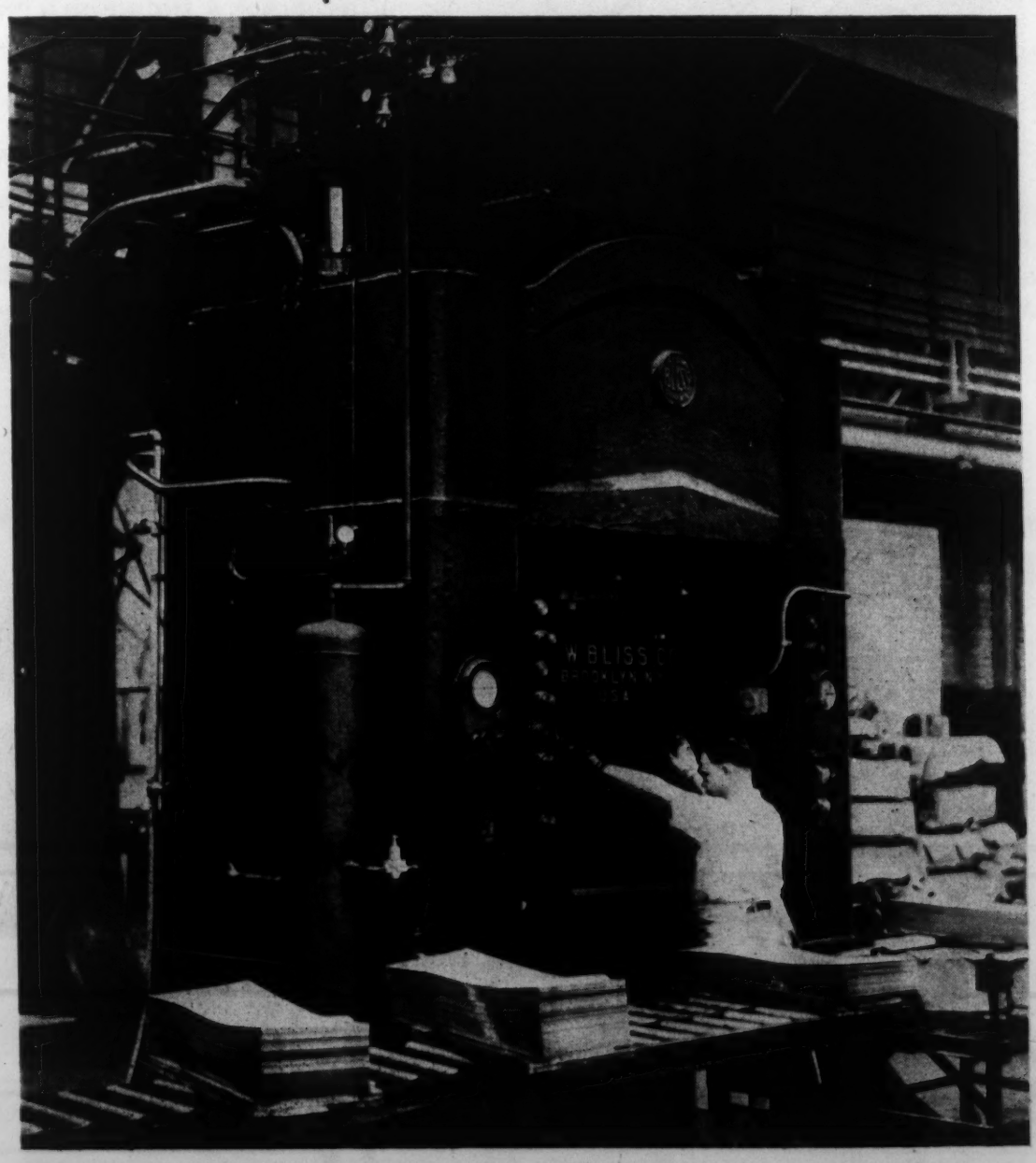
The feed drive is electronically controlled, making it possible to adjust feed rates while machine is feeding by operating a potentiometer knob.

Single Action Press Forms Sheet Metal Parts

A new single action hydraulic press of 1,500-ton capacity for drawing and piercing has been designed by *E. W. Bliss Co.*, 450 Amsterdam St., Detroit. One such housing-type press installed in the General Electric Erie plant is used to draw and pierce 0.025-in. thick stainless-steel evaporator plates for home refrigerators, and can be used to produce blanked, stamped, formed, pierced, trimmed, drawn, and embossed parts from sheet metal.

The press is equipped with a 12-in. ram stroke and an hydraulic drawing cushion stroke of 6 in. The installation includes a frame with fully shrunk tie-rods and keyed housings; positive drive of closing stroke; universal electric control, providing for speed change and reversal; safety control, for instant stopping at any point; convenient pressure adjustment; delayed action of cushion return, allowing slide to raise from work before the finished piece is stripped from the die.

Reversal is effected automatically by either predetermined pressure or position of the slide. Height, installed, is about 183 in. above floor level. Press speeds, in in. per min., are: quick advance, 750; pressing, 17; return without cushion, 675; and return with cushion, 340.



This press is used to draw and pierce stainless steel evaporator plates for home refrigerators.

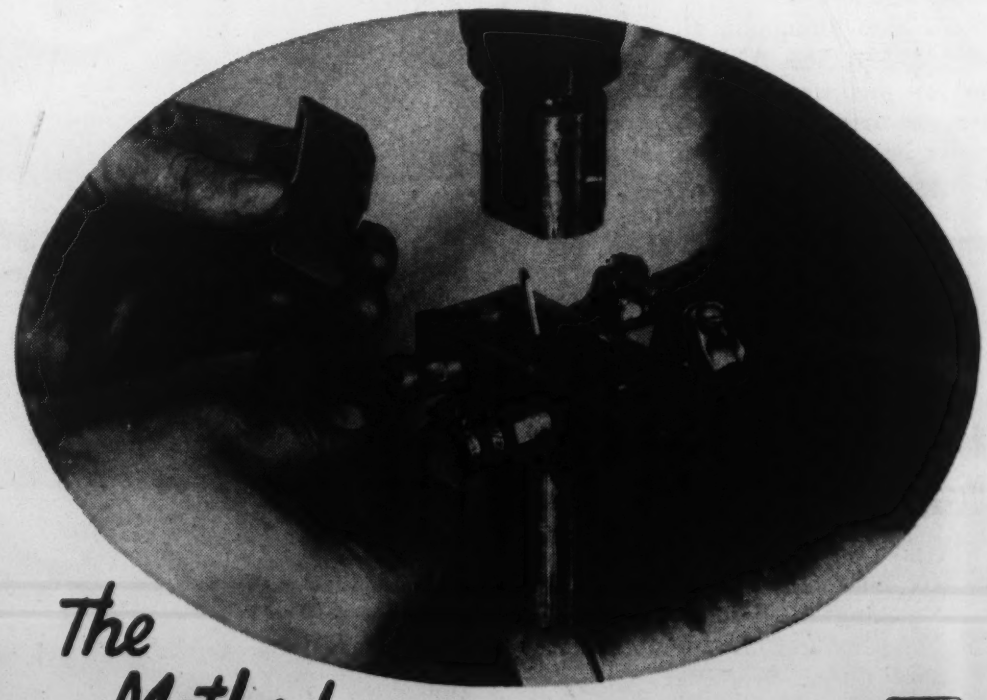
WELDINGENUITY cut the cost 75%

Dedoes of Berkley, Michigan had developed some attractive flush hardware—with no projecting parts—for kitchen cabinets. To make it, however, the trigger cam had to be attached to the finger plate at a compound angle and no surface markings were permissible on the front of the finger plate. Silver brazing seemed the only way out.

Then Progressive's Process Engineering Department looked it over, designed a simple fixture to hold the parts in a projection welder. The two pieces are now rigidly assembled by welding at a clip of 600 an hour at one-quarter of the former cost.

Whether it's a simple machine to turn out a small part or a complex automatic to perform multiple welding operations, Progressive can show you the lowest cost way to do the job.

Are you receiving the Monthly Welding Pictorial? It is full of ideas on lower cost welding methods. Write for it today on your company letterhead.



The Method

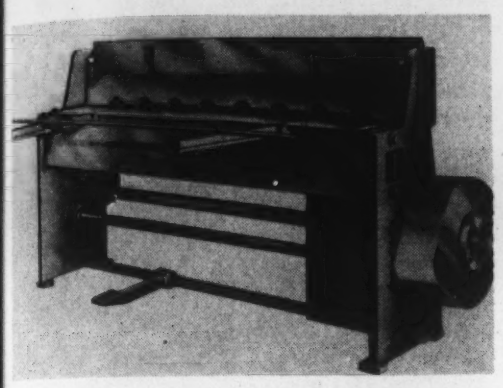
Progressive Welder Co. 3050 E. OUTER DRIVE • DETROIT 12

RESISTANCE WELDING EQUIPMENT

Power Cutting Shears Have 4-Way Blades

For all types of shearing and trimming up to 14-gage capacities, *Parker Manufacturing Co.*, Santa Monica, Calif., has introduced a new line of all-steel power squaring shears. Known as Parker Power Squaring Shears, they are built from steel plate of box type design, welded and normalized to relieve stresses.

Since the shears stand only 47 in. high, they have a low center of gravity. Cutting length is 73 in.; blade length, 75 in.; back gage range, 18 in.; front gage range, 38 in.; strokes per min. (50 or 60 cycle), 85. A 2-hp. motor is furnished with the shear.



The 4-way design blades in these shears increase blade life and reduce time lost for grinding.

The shears will cut drawn or folded parts within 1½ in. of the shoulder; thus, deep-drawn objects (sinks, basins, cowlings, etc.) can be trimmed closer. The blades are of 4-way design. They are equipped with front, back and side gages, and T-slots are provided in the bed and brackets for the front gage. The back gage is a double bracket screw type, and adjustable. Positioning of the gage is accomplished by one handwheel. Taper cutting is accomplished by disengaging the coupling.

Speed of operation is up to 85 strokes per min. with practically instantaneous engagement of the clutch.

Extruded Nylon Rods Can Be Machined

A new technique to extrude nylon plastic in rods ranging from ⅛ to 2 in. in dia. and from 2 to 4 ft. in length and accurately machining them has been developed by the *Polymer Corp.*, Reading, Pa.

Previous products of nylon plastic have been made by extrusion or molding. Thus, abrasion-resistant sheathing for electrical wiring was extruded by pressure through a die. Other products—combs, tableware, valve seats, gaskets—were injection molded, *i.e.*, forced by pressure into molds of suitable design.

The new rods, using Du Pont's FM-1 nylon molding powder, open the field of nylon to manufacturers whose volume of production does not warrant the expense or time necessary to obtain injection molds, but whose products can practicably be made by machining.

The new development is important to mass producers of molded products, too. Engineers can now try out projected applications by preparing machined samples for tests before expensive molding equipment is purchased.

The use of nylon in the new form seems feasible for bearings and other wear-resistant parts, particularly in applications where problems of lubrication are difficult.

Combined Operations of Drilling and Tapping Available in One Machine

The combined operations of conventional radial and horizontal drilling and tapping machines are available in the new series of universal horizontal drilling and tapping machines, designed and built by the *Kaukauna Machine Corp.*, Kaukauna, Wis. These units can drill and tap at any angle in any plane within the maximum and minimum limits of travel or movement of the machine units.

One of the advantages of this equipment is that it eliminates multiple set-ups and hand drilling and tapping operations. Their portability, flexibility of operation, and operating range permits their being moved to bulky and unwieldy workpieces.

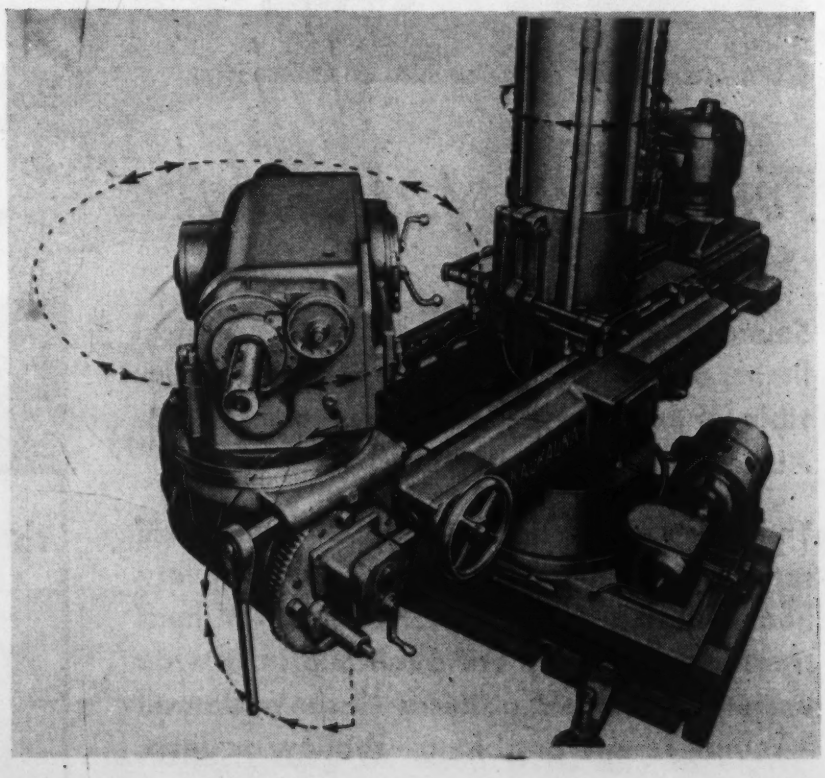
An important feature of these portable universal drilling and tapping machines is the head which swivels 360 deg. in either a horizontal or vertical plane. Thus, it is possible to operate the spindle, which has a 12-in. continuous travel, in any angle. The headstock is positioned on two individually controlled axes to permit the head to swivel 360 deg. on a trunnion, and the trunnion to swivel 180 deg. The two rails, supporting the head and trunnion, have a 24-in. horizontal traverse, and their movement is accomplished through dual handwheels with dual hand-clamps locking the rails into position.

In addition, the rail can be raised or lowered by power and be positioned at any point that is suitable to perform the machining operations. The rail may also be swiveled through 360 deg. to perform machining operations at any point.

Three spindle feeds are provided, and the drive to the spindle consists of a 9-speed gear change box, with a direct drive to the spindle through the necessary gears and drive shaft.

A total of 36-in. spindle movement radially from the center of the column is available, since the head is mounted on two horizontal rails which have a 24-in. horizontal adjustment and the spindle has a 12-in. continuous travel.

To facilitate handling machining operations on long workpieces, the column is supported on a traveling column base which has a 48-in. power travel.



This machine can drill and tap at any angle in any plane within the maximum and minimum limits of travel of the unit.

There are three models in the series: Model 125-U Universal unit is a completely universal machine and will drill and tap holes at any angle. The No. 125-HR and 125-H machines are horizontal machines. The HR machine has the head mounted on two horizontal rails, having a 24-in. horizontal adjustment. Model 125-H has a smaller range of application, and its compactness makes this unit adaptable to lowering into small vessels or for operation in cramped areas.

Thermalloy Pots for QUALITY-DEPENDABILITY-LONGEVITY in HEAT TREATING SERVICE

HEAT AND CORROSION RESISTANT

For long useful service

M-26

Sound foundry practice, controlled chemical limits, and X-Ray control are greatly responsible for the successful performance of THERMALLOY annealing pots and covers.

There is a grade of THERMALLOY which will render maximum service life under every heat treating condition. THERMALLOY heat treating containers are available in a wide variety of sizes and patterns—large and small—round, square or oblong—shallow or deep.

Whether it be a MUFFLE, RETORT, BASKET, BOX or TRAY, you get more for your money when you buy THERMALLOY.

AMSCO ALLOY *and* THERMALLOY *are identical*

X-RAY CONTROLLED

MUFFLES
RETORTS
BASKETS
CHAIN
BOXES
TRAYS
FURNACE PARTS

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION

ELYRIA, OHIO.

New Compounds Aimed at Greater Cleaning Efficiency and Speed

E. F. Houghton & Co., 303 W. Lehigh Ave., Philadelphia 33, has announced a new series of metal and maintenance cleaning compounds. These are known as the Houghto-Clean 200 Series, and include 17 different products including cleaners for maintenance work, ferrous and nonferrous metals, for use prior to painting or vitreous enameling, electrolytic cleaners and special purpose compounds.

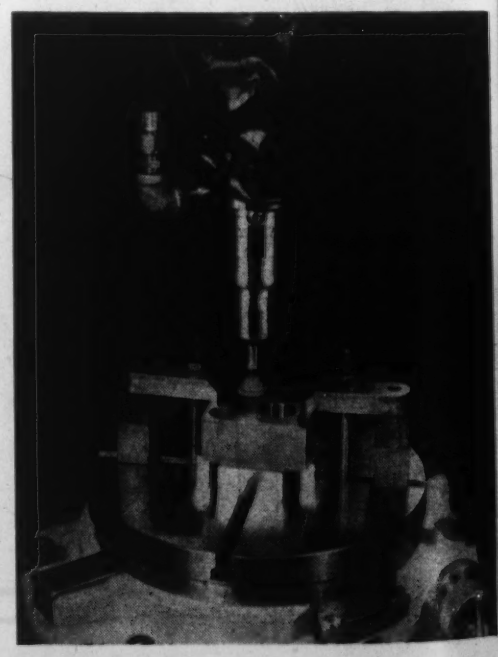
Advantage has been taken wherever feasible of recent developments in detergency and wetting out. The aim in developing the compounds was to provide increased speed and greater efficiency so that alkaline cleaning can be used in the production line with a considerable saving of time as compared to former practice.

In evaluating these cleaners, ultra violet light was used in a fluorescent test. Visual inspection of cleaned parts or the formerly accepted waterbreak test were not deemed sufficient to measure the comparative values of metal cleaning compounds. Reproducible results are obtained with this method of fluorescent testing.

Attachments and Fixtures Increase Versatility of Machine Tools

Attachment for Converting Machine Tools to Jig Grinders

A high-speed air-driven attachment, called Vulcanaire, for converting jig borers and other machine tools into precision jig grinders, has been developed by *Vulcan Tool Co.*, Dayton, Ohio. The attachment is



This air-driven adaptor can be used to convert machine tool equipment for precision jig grinding.

equipped with an adaptor that fits into the chuck of any machine tool when the operation requires precision jig grinding.

It has controllable speeds ranging from

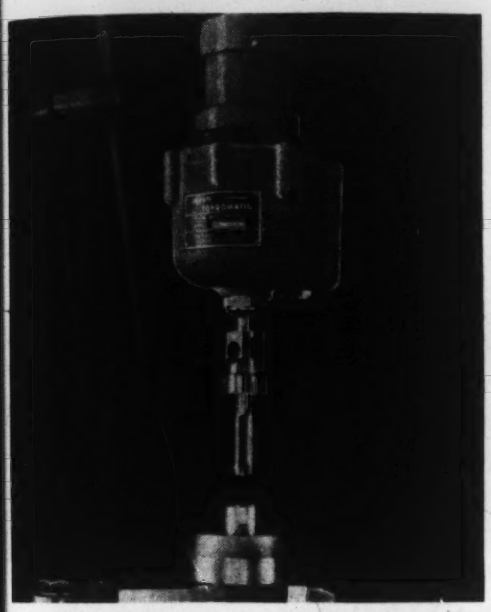
(Continued on page 147)

30,000 to 75,000 r.p.m.; 4 to 8 cu. ft. of air per min. is required for the complete speed range. The unit is 2½ in. maximum dia. and, exclusive of adaptor and grinding wheel, is 7½ in. overall. Precision grinding of holes from 1/16 in. to 1½ in. can be accomplished. The complete unit includes adaptor to fit any specific machine tool, together with dust collector, air filter, pressure gage and oiler.

In addition to jig grinding applications, the attachment is produced in models for adapting lathes, milling machines and internal and surface grinders for other high-speed precision grinding.

Torque-Driven Tapping Attachment

A universal torque-driven tapping attachment, available in three sizes, has been announced by the *Charles L. Jarvis Co.* of



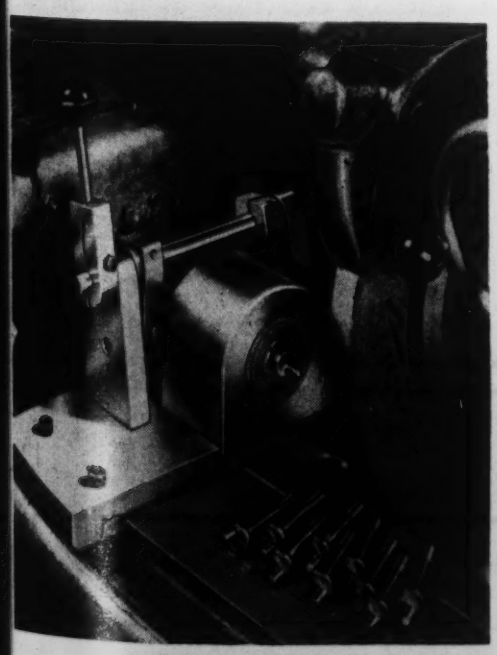
The tapping attachment can be supplied to fit any drill press or tapping machine.

Middletown, Conn. Known as Torquomatics, the attachments will tap from soap to copper or chromium nickel steel. They come in standard and built-in models, and can be furnished to fit any drill press or tapping machine.

Collet Fixture for Plain Grinding Machines

A collet fixture to increase the usefulness and step up the production of a standard plain grinding machine has been designed

(Continued on page 148)



The collet fixture in operation on a standard plain grinding machine.

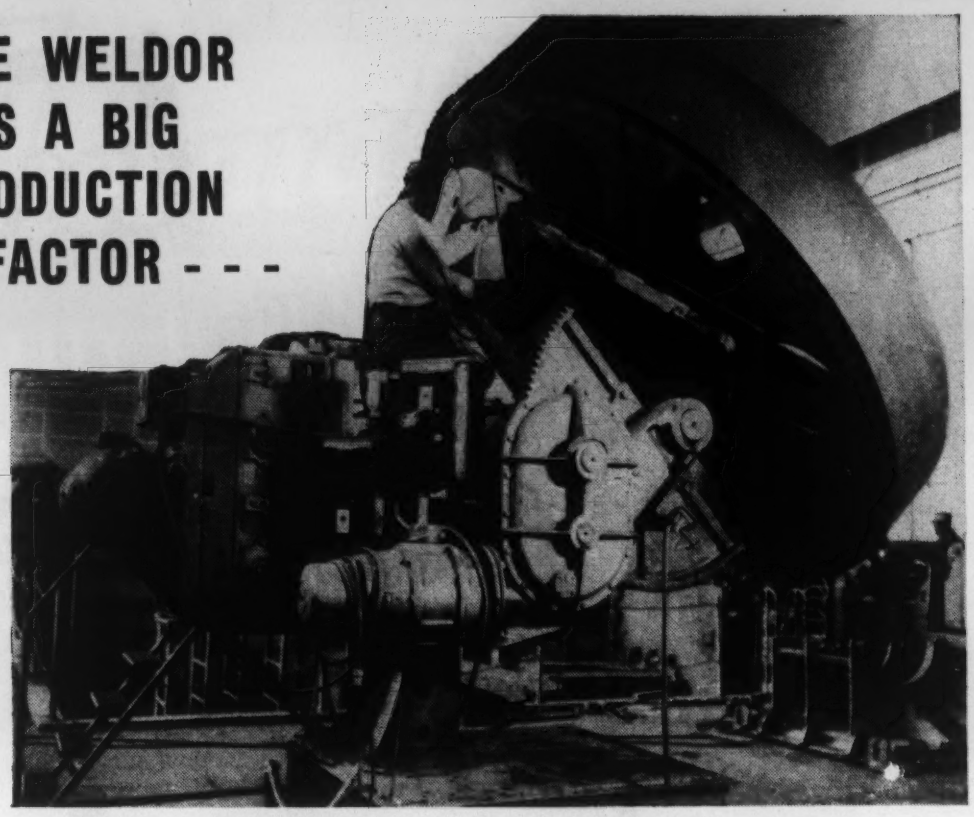
Alnor PYROCON

the contact pyrometer for quick, accurate surface temperatures

Designed to meet foundry and industrial plant needs, this all-purpose surface temperature pyrometer provides readings in a few seconds of molten metals, liquids, bulk materials, and flat or curved, stationary or moving surfaces. The rugged, shock-resisting pyrometer movement may be used with any of eight standard thermocouples, interchangeable without adjustment or re-calibration. Choice of rigid or flexible arms. Built in several standard scale ranges, 0-300 to 0-1200 F. Write for bulletin with complete description.

ILLINOIS TESTING LABORATORIES, INC.
420 N. LA SALLE STREET • CHICAGO 10, ILLINOIS

THE WELDOR IS A BIG PRODUCTION FACTOR - - -



Your welders are *big* production factors when they work with C-F Welding Positioners because these power operated Positioners with variable speed table rotation are real production tools. Better automatic welding is possible because the C-F Variable Speed feature governs table rotation speed from 0 r.p.m. and up—assuring better control of fillet in circular or peripheral automatic welding.

If increased production, better downhand welding and lower costs in your welding department can help you meet the competition for new markets, C-F hand and/or power operated welding positioners should be your first choice. Write for Bulletin WP 22.

C-F positioned welds mean better, more economical welds

CULLEN-FRIESTEDT, CHICAGO 23, ILL.

IMMERSION HEATING WITH VITREOSIL (Vitreous Silica) HEATERS

When other methods are unsatisfactory, acid solutions in tanks of any material can safely be heated by Vitreosil electric immersion heaters.

VITREOUS SILICA — VITREOSIL — REG'D TRADE MARK

SEND FOR BULLETIN #2

THE THERMAL SYNDICATE, LTD.

12 EAST 46th STREET, NEW YORK 17, N.Y.

by *Zagar Tool, Inc.*, 23880 Lakeland Blvd., Cleveland 17. Used to grind parts without centers, which can be held in collets, this tool runs on its own ball bearings and is driven by the headstock of the machine. The collet can be opened and closed while the grinder is running. Because the collet does not move lengthwise, it is possible to hold overall dimensions.

This collet tool is adaptable to any make or model of grinder, and its use involves no extra or special attachments.

Shell End Mills

A new line of carbide tipped and tantung tipped shell end mills, manufactured in right and left hand styles, has been announced by the *Vascoloy-Ramet Corp.*, North Chicago, Ill. They range in size from 2½-in. O.D. to 4½-in. O.D. and bores 1 in. to 1½ in.

The carbide tipped shell end mills are available with negative radial and axial rake angles for milling steel, and zero rakes for milling cast iron, nonferrous and nonmetallic materials.

Neoprene-Mounted Toolholder

Holes only 15/16ths center-to-center can be tapped with a new Neoprene-mounted, positive drive tool holder, according to the *Burg Tool Manufacturing Co.*, 5028 W. Jefferson Blvd., Los Angeles 16.

This new product has Acme-threaded shanks for use on multiple-spindle tapping operations. Four parts make up the tool holder: shank, collet, oil-resistant Neoprene mounting, and locking ring.

Neoprene mounting is used to minimize tap breakage and compensates for misalignment. Bell-mouthing, and over-sized holes are said to be eliminated by the full-floating mounting.

Toggle Machine Punches Wide Range of Steel Shapes and Sections

A new size 12 toggle machine, designed to handle a wide range of structural steel shapes and sections for both flange and web punching in one handling, is being manufactured by *Beatty Machine & Mfg. Co.*, Hammond, Ind. Special tools for a variety of punching requirements can be applied on this machine; die space can be modified if wider ram face is required.

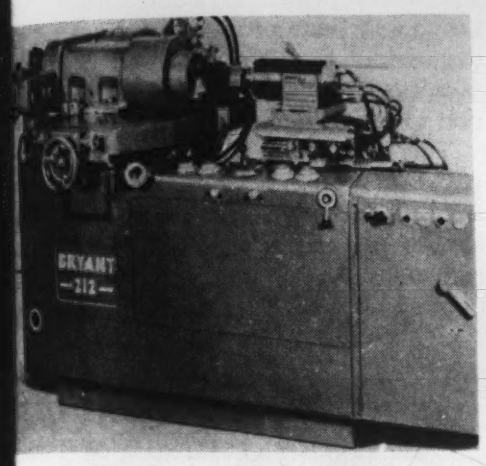
Punching tools with double-gag punching and die holders provide two diameters on each pitch line, which saves time and eliminates re-handling, since the two diameter holes can be punched on the same pitch line without loss of time spent in changing tools. Control levers for duplicate punching are provided.

The die space provided by this equipment is 36 in.; the throat is 25 in.; and the stroke is 1¾ in. The capacity of the machine is 137 tons and requires a 7½-hp. motor. The face of the table is 49 by 22 in. It can handle plate widths up to 48 in.; I-beams, 6 to 24 in.; H-columns, 14 in.; channels, 18 in.; and angles 8 by 8 by 1 in.

Automatic Internal Grinder Requires Minimum Operator Attention

A precision automatic internal grinder has been so designed by *Bryant Chucking Grinder Co.*, Springfield, Vt., that where required, one or more machines can be operated by the same operator. The various movements of the machine are hydraulically operated to afford flexibility of operation between the various units. Cycle control is accomplished electrically so that the cycle can be readily changed to suit varying working requirements.

The machine has a 9-in. swing inside the standard water guard and a 12-in. total wheelslide traverse. The cross feed is obtained by lateral motion of the workhead, which is supported by anti-friction bearings



Three methods of automatic sizing can be provided for this internal grinder.

of the roller type. The machine is suited for grinding work with bores from 5/16 in. in dia. up to 3½ in. in dia., and the grinding traverse permits grinding of 3-in. bore lengths. For the smaller ranges of bores, Bryant wheel spindles operating up to 100,000 r.p.m. can be used. Standard or special tooling may be used in conjunction with the machine to satisfy the particular needs of the customer.

Three methods of automatic sizing can be provided for this machine. The basic machine is equipped so that change over from one method to either of the others can be accomplished merely by the addition of the sizing equipment.

Sizing from the truing diamond is accomplished by predetermined advance of the wheel beyond the wheel truing position, which is performed between the rough and finish grinding positions of the cycle. Wheel wear is automatically compensated for by the machine.

Automatic plug sizing is accomplished by a plug gage, mounted in the work spindle, which automatically checks the bore size after each pass of the grinding wheel. As the plug gage enters the bore, the machine automatically stops grinding and the wheel withdraws from the bore ready for loading of the next workpiece.

A third method of sizing can be applied in which a diamond tipped finger, contacting the bore as it is being ground, operates electrical contacts at the proper time to arrest the grinding action and withdraw the wheel from the bore, ready for the insertion of the next workpiece.

25th Anniversary

MAC DERMID
Bright Copper
PLATING PROCESS

MAC DERMID
★ Incorporated ★
WATERBURY 88, CONNECTICUT

INSTANTANEOUS ACCURACY with ENGELHARD Portable Indicating Pyrometers

Engelhard Portable Indicating Pyrometers combine the necessary attributes of accuracy and instancy which distinguish the completely efficient precision instrument.

High resistance per millivolt assures a degree of accuracy unaffected by connecting lead length or by thermocouples of different resistances.

Direct deflection construction permits instantaneous readings easily in either millivolts or degrees.

The conveniently portable instrument is a complete unit in a sturdy carrying case with removable cover.

The 6" scale length indicator may be calibrated with 100 to 150 divisions. Scale range may be selected to suit specific applications. Every indicator is equipped with the Engelhard frictionless moving coils.

All indicators may be furnished with two scale calibrations —for rare metal and base metal thermocouples. By a simple change of lead connections readings are made on either scale.

WRITE FOR BULLETIN 400

CHARLES ENGELHARD, INCORPORATED
90 CHESTNUT ST., NEWARK, NEW JERSEY

Minute Leaks in Vacuum Located with Portable Leak Detecto

A new portable leak detector that c locate and measure leaks in vacuum a pressure systems as minute as 0.000000 cc. per sec. is now being manufactured b the *Consolidated Engineering Corp.*, De BR, 620 N. Lake Ave., Pasadena, Cal Based on the mass-spectrometer princip this instrument electronically separates a measures helium molecules from all di similar molecules in the atmosphere. I troduction of helium in suspected are will give an almost immediate indicatio on the visual meter or audio alarm syste whenever any leakage is present.

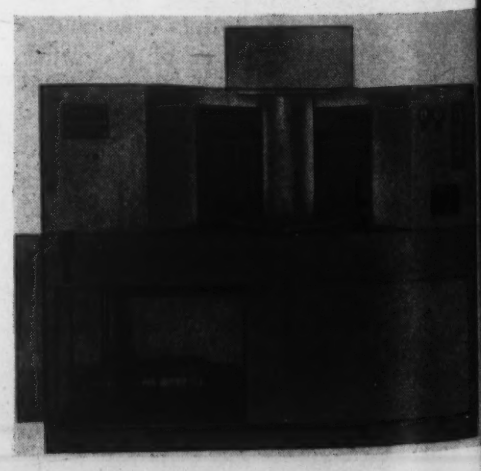
Selection of sensitivity over six differe ranges can be had for measuring almost a rate of leakage. Size of the leak can also b determined with the audio system whe using a helium probe at a distance fro the instrument. The pitch of the leaka warning signal changes roughly in propo tion to the leak size.

The instrument is portable, and is in stalled in a cabinet 43 in. high, 25 in. dee and 22 in. wide and mounted on ball bearing rubber tired casters. The equipmen is operated from a standard 115-v., 60-cyc lighting circuit.

Turntable Washing Machine Handles Small and Medium Parts

A turntable type washer, which bot rinses and dries average sized parts i baskets, trays, or individually, is now bein marketed by *Mabor Co.*, Clark Township Rahway, N. J. This machine has bee developed to take care of cleaning problem where space is at a premium and when single operator can easily handle a load o light parts or medium size parts.

The machine is essentially a turntabl with a vertical shaft resting on two ball



This turntable washing machine require only one operator to load and unload th parts for cleaning.

bearings. The turntable is located at work ing height in a square cabinet type washer. Parts are loaded and unloaded at the same location either by means of trays or baskets or by simply loading the parts on a specia tray fastened to the turntable. The parts

(Continued on page 151)

e submitted to washing solution sprays, en drained, then rinsed, drained and ied by cold or hot air jets. Each of these ree operations takes place in a closed amber.

The solution is taken from large tanks cated under the turntable and then forced rough spray nozzles by means of two mps. Rotation of the turntable may be ther continuous or intermittent, according the type of parts. A small motor with eed reducer drives the turntable. Solu- ons are continuously filtered and heated adequate means such as steam coil, im- ersed combustion gas burner, oil burner electric heater.

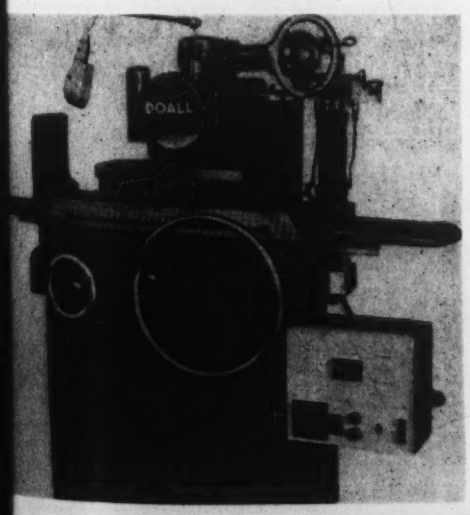
This machine is particularly handy when large number of small parts have to be eated continuously by the same operator ho operates another machine. For instance, r die castings coming from the machine stampings coming from the press, etc. his machine is made in many dimensions, e most common is 6 ft. by 6 ft. and will ndle one to three ton of parts per hr. sily.

Alterations can be made to standard uipment to fit special needs, such as in- de cleaning of hollow cylinders, applica- on of various chemicals like phosphatation gents, etc.

Hand-Operated Grinder Designed for Close Tolerance Work

A hand-operated surface grinder designed r close tolerance grinding work in tool oms has been announced by the *Doall* o., 1301 Washington Ave., South, Minne- olis 4.

Known as Model GH, it has a cartridge pe direct drive spindle with automatic



his hydraulically operated surface grinder atures a cartridge type direct drive spindle.

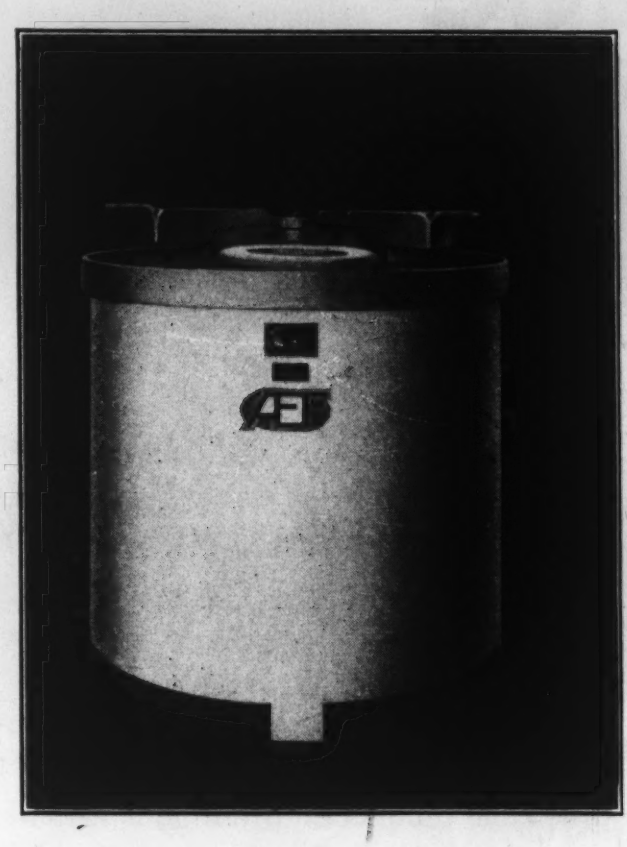
ke-up for wear. The direct coupled 11- p. motor and the spindle are statically and namically balanced and are totally en- osed.

The grinder has a one piece base and lumn support construction with the lumn itself extending from the bottom the base clear up to the spindle. The evating screw and the cross feed screw erate through 4-in. bronze nuts to mini- ize wear.

(Continued on page 152)

LOOK!

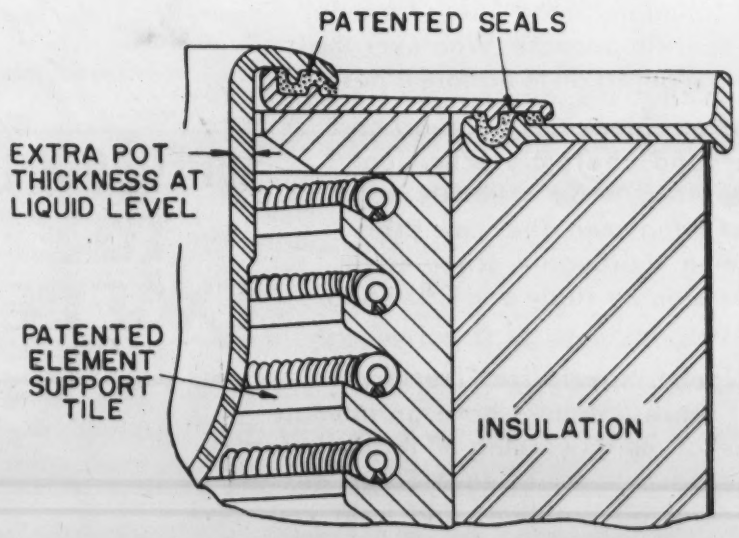
for these features when buying, then buy "AMERICAN" pot furnaces



Model P1618—16" dia., 18" deep

- Double flange pot
- Double flange supporting ring
- Double flange top ring
- Extra pot thickness at liquid level
- Element — one continuous helix extra heavy rod
- Positive element support in recessed refractory wall
- Lining 12¾ inches
- Two point heat control
- Time clock starting
- Easily operated insulated top covers

For Use with LEAD – SALT – CYANIDE

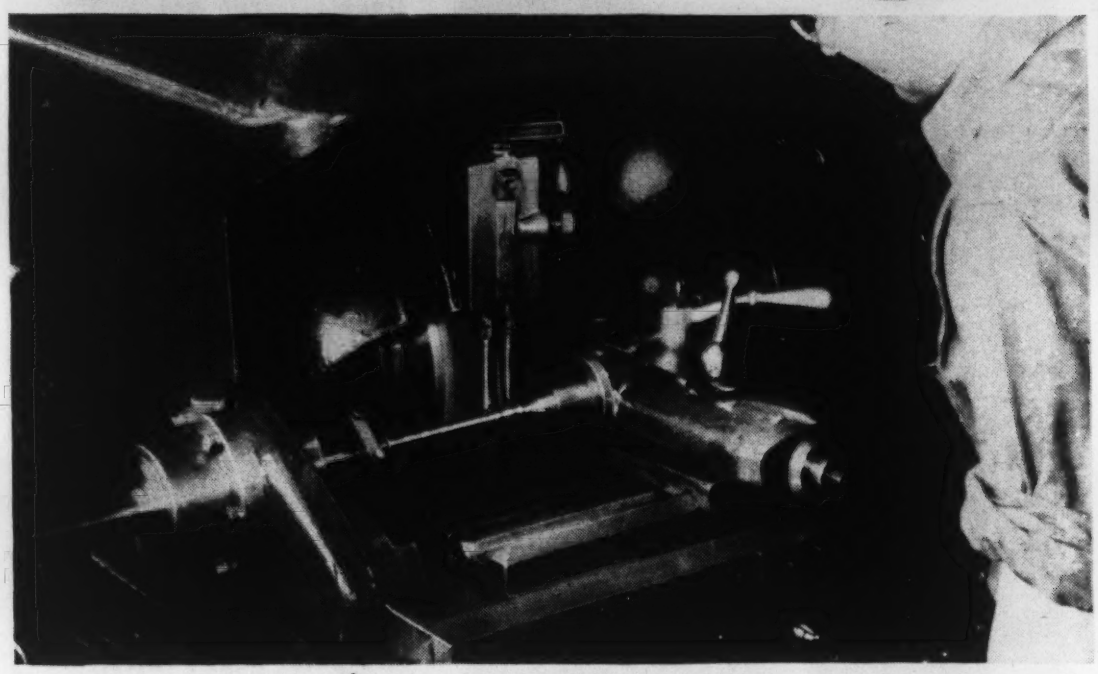


American Electric Furnace Company

29 Von Hillern Street, Boston, Mass., U. S. A.

Industrial Furnaces for All Purposes

3 point service



. . . for better precision grinding!

The use of straight oils for precision, production grinding is resulting in spectacular improvements in finish, and making it possible to grind within tolerances never before thought practicable. If you want better grinding, it will pay you to investigate the Stuart line of grinding oils.

To improve metal-working efficiency, take advantage of Stuart 3-point service:

1 ***The right oil for the job*** . . . every oil in the complete Stuart line is formulated for a specific purpose. Whatever the job, there is a Stuart oil to handle it best.

2 ***Sound engineering*** . . . Stuart engineers and laboratory technicians are neither text-book theorists nor self-taught handymen. They are practical oil men thoroughly schooled in their profession by study and first-hand experience.

3 ***Intelligent, specialized service*** . . . Stuart representatives have an intimate knowledge of metal-working oil requirements, and of the advantages of each Stuart oil. They will study your oil problems and help you solve them. For further information, write for "Grinding With Oil," a 12-page booklet.

ThredKut 99
. . . for grinding tough, stringy metals . . . makes grinding wheels "*act harder.*"

SUPERKOOL 81X
. . . for precision grinding on metals in middle range of grinding hardness.

EXCELENE
. . . for grinding hard steels . . . makes grinding wheels "*act softer.*"

D.A. Stuart Oil Co.
EST. 1865 LIMITED
2745 SOUTH TROY STREET, CHICAGO 23, ILL.

STUART *service goes with every barrel*

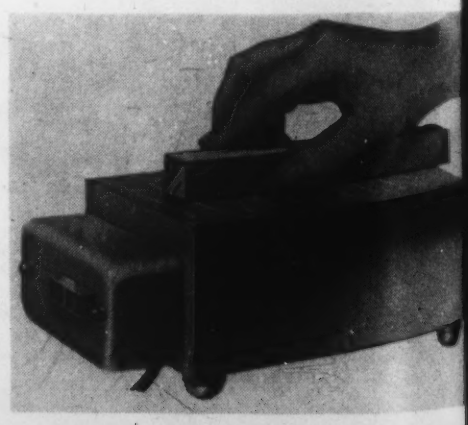
The hand wheel for the spindle elevati screw is graduated in half-thousandths wi vernier adjustment to 0.0001-in. The han wheel for cross feed is graduated thousandths with vernier adjustment al to 0.0001-in. Working area of the tab is 6½ by 19¾ in. with maximum wo height of 12 in. using the standard 7 ½ by 1¼-in. grinding wheel.

● A new proportioning control burner f use with fuel oil that has an air and o interlock which maintains the air and o ratio constant at any setting between hig and low setting has been developed *Johnston Manufacturing Co.*, 2825 E. He nepin Ave., Minneapolis, Minn. After on set and adjusted to produce the desired fu nace atmosphere, the burner requires further regulation. Various types of contr motors can be used and are normall mounted on the burner to provide accura control. Control hookups are available f furnaces with several burners, and simp connections can be made to synchronize a number of them.

Tool Demagnetizer Effectively Uses Flat Top Grid

For demagnetizing large and small piece and especially for drills, punches, reame tools and dies that have been in contact wi a magnetic chuck, *Luma Electric Equipme Co.*, Toledo 1, Ohio, has developed a d magnetizer. One pass over the flat top gr demagnetizes small pieces. For heavy, har to-handle pieces, it is necessary to pass t instrument over and around the magnetize work to accomplish complete demagnetizin

Among the features of this demagnetiz is its segmented flat top grid, with segmen placed to most effectively spread the ma netic field over the surface of the gri Thus, full and equal demagnetizing cap bilities are found in any spot or area of t



The grid surface of demagnetizer has a hig finish to eliminate scratching of parts bei processed.

grid top. The grid surface is ground to mirror-like finish to eliminate any poss bility of scratching the pieces being dema netized.

An automatic self-resetting switch, acti in the dual capacity of overload cutout, provided to protect tool against prima surges. The unit is completely protected b an aluminum case.

News of...

ENGINEERS COMPANIES SOCIETIES

Engineers

Rollo E. Falk opened up offices at 7 John St., New York, on Jan. 1 as consultant in operating problems in the nonferrous metal industry, having resigned from Revere Copper & Brass, Inc., where he was vice president in charge of manufacturing and a director. He has been in the nonferrous field for 28 years, having been works manager and vice president, Dallas Copper & Brass Co., Chicago, prior to its merger with Revere.

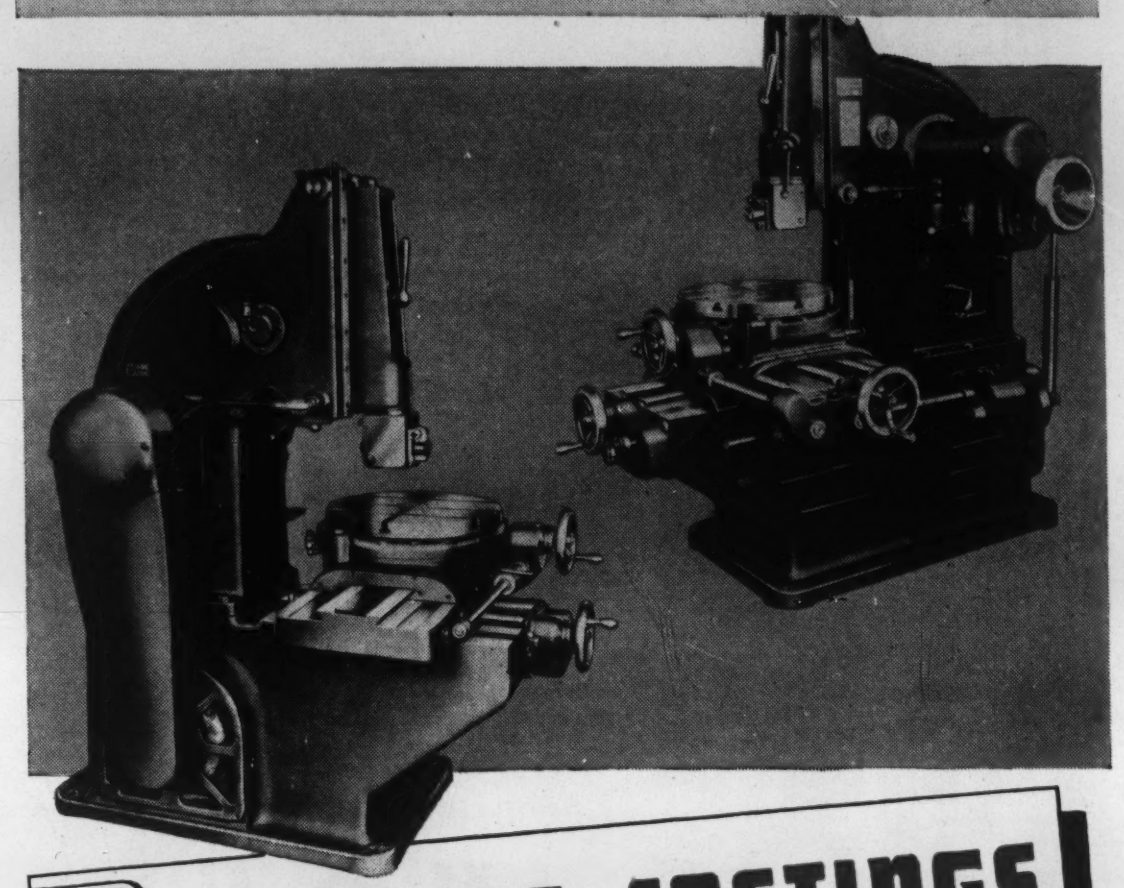
A. R. Stargartder has become chief metallurgist, Washington Steel Corp., Washington, Pa. He was formerly chief metallurgist, Eastern Stainless Steel Corp., and prior to that, chief metallurgist, Gillette Safety Razor Co., having originated its "blue blade". He was a member of the War Production Advisory Committee.

Dr. Robert Hollenbeck Aborn has been made assistant director, research laboratory, U. S. Steel Corp., at Kearny, N. J. He won his B.S. and doctor's degree at Massachusetts Institute of Technology. He has been with Bethlehem Steel Co., Watertown Arsenal, and instructor in engineering at Harvard. Prominent in welding research, he won the Lincoln medal of the American Welding Society in 1941. He served with the War Metallurgy Committee, Office of Scientific Research & Development.

C. E. Herington, director of advertising and sales promotion, Meehanite Metal Corp., New Rochelle, N. Y., has been made manager of a new department, sales engineering, which will provide an advisory engineering service to users of castings and assist in applications, design and sources of supply.

Robert M. Conklin, mechanical engineer, has joined the staff of Battelle Memorial Institute, Columbus, where he will do research in production materials and processes. He was formerly development engineer with Western Electric Co. and is a member of Tau Beta Pi, honorary engineering society.

"not only to serve today, but to anticipate tomorrow"
Wm. B. Given, Jr.



MEEHANITE CASTINGS
as made by BRAKE SHOE

...help to avoid vibration in P&W Vertical Shapers

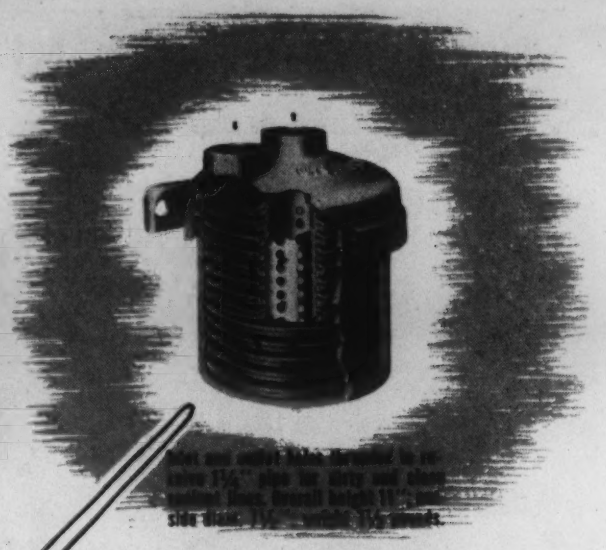
IN making vertical shapers in 6-inch and 12-inch sizes, Pratt & Whitney Division, Niles-Bement-Pond Company took all possible steps to avoid vibration. One very important decision was the selection by P & W metallurgists of Meehanite castings made by Brake Shoe for all main castings of both shapers, including the bases.

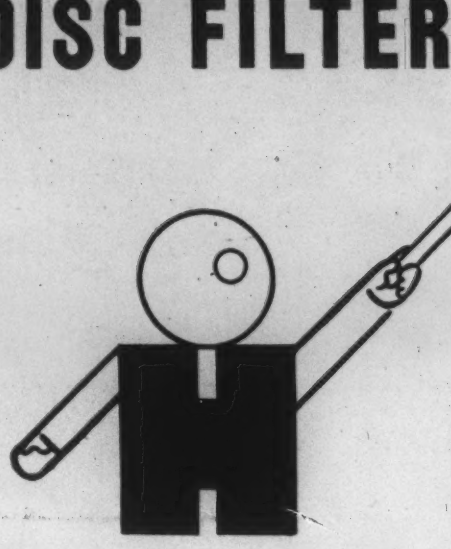
Superior damping capacity at a high stress range was only one of many requirements when these castings were chosen. Included also must be rigidity and the required high degree of strength which Meehanite castings also provide. As a result, smooth easy operation is promoted and accuracy maintained.

Physical and metallurgical properties that are "made to order" are available to users of Meehanite castings on a production-schedule basis. The range of types is so wide that *your work specifications are the casting specifications.* And, like a good machine tool, Meehanite castings made by Brake Shoe are soundly based – based on the experience, knowledge of foundry technique, and the research-plus-production facilities of the entire Brake Shoe organization.

Brake Shoe
BRAKE SHOE AND CASTINGS DIVISION
230 PARK AVE., NEW YORK 17, N. Y.

the NEW HOFFMAN DISC FILTER





HAS THESE OUTSTANDING FEATURES

- LOW INITIAL COST
- OCCUPIES LIMITED SPACE
- NO MOVING PARTS
- EASY TO CLEAN
- EASY TO INSTALL

The Hoffman Disc Filter can be installed either singly or in units and delivers a continuous flow of clean coolant. Ideal for use where space is limited and low initial cost is a factor. The removable disc element can be quickly and easily cleaned and re-used. Maintenance costs are kept at an absolute minimum.

The Hoffman Disc Filter will remove dirt particles measuring from 3 to 5 micro inches and is being successfully used on screw machines and thread rolling coolants, diesel engine lubricating oils, hydraulic oils and various wash oil applications.

★ SEND FOR LITERATURE

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223 Lamson St., Syracuse, N.Y.
COOLANT FILTERS · FILTRATION ENGINEERING SERVICE

News of...

ENGINEERS COMPANIES SOCIETIES

Stephen M. Shelton, metallurgical technologist, has been made chief of the Albany, Ore., division, Bureau of Mines Metallurgical branch, succeeding *Bruce A. Rogers.* He will be in charge of research in zirconium, carbothermic magnesium, iron-phosphate ores, iron-nickel ores, electrolytic zinc and nonmetallic minerals. He was responsible for manufacturing electrolytic manganese from manganese ore.

J. D. Seiler has been made assistant works manager, Milton, Pa., plant, American Car & Foundry Co., having been with the company for 40 years, with chief inspector and general superintendent among positions held.

Ralph M. Heintz will temporarily supervise production for Jack & Heintz Precision Industries, Inc., in addition to duties as vice president in charge of engineering. He is well known as a speaker on engineering and technical subjects.

Frank B. Lounsberry, vice president in charge of methods and processes, Allegheny Ludlum Steel Corp., has become technical director, succeeding *Vere B. Browne,* pioneer in development and manufacture of magnetic and stainless steels, who retired Jan. 1. Mr. Lounsberry has served many steel companies, including Holcomb, Atlas and Hunter Crucible.

Abner B. Wellborn has become superintendent, metallurgy division, General Electric's chemical department, Pittsfield, Mass. *Ernest E. George* has been named engineer. *V. J. Rauer, G. M. Patton* and *R. G. Mussen* have been appointed to supervisory manufacturing positions.

J. B. Van Der Werff has become chief engineer, electronics division, Ellinwood Industries, Los Angeles, having received a master's degree in mechanical engineering in 1938 from California Institute of Technology. *A. G. Willauer* has been made assistant project engineer in production of the company's new engine, having been in charge of the hydraulic and research laboratory at Adel Precision.

S. T. Powell has been made manager of manufacturing, General Electric's Wire & Cable Div., Bridgeport, Conn.

Lee C. Daniels has been appointed chief engineer, Towmotor Corp., Cleveland, maker of fork lift trucks and

(Continued on page 157)

News of...

ENGINEERS COMPANIES SOCIETIES

industrial tractors, having formerly been with the Oliver Corp., Cleveland Tractor Co., Twin Coach Co., and White Motor Co.

B. M. Stubblefield, assistant general superintendent, Campbell Works, becomes general superintendent of the Campbell works steel plant, blast furnaces and Struthers works of the Youngstown Sheet & Tube Co. *J. S. Stanier,* superintendent, hot and cold strip mills, becomes general superintendent of flat rolled and tubular mills. *W. H. Yeckley,* superintendent, Brier Hill works, will become general superintendent at Brier Hill. *C. J. Daley,* assistant superintendent, sheet and cold strip mill, becomes superintendent of the cold strip mill. *J. E. Finnie,* assistant superintendent, hot strip mill, becomes superintendent of that unit.

Charles Burton Thwing, Ph. D., pioneer in the field of pyrometry and president of the Thwing-Albert Instrument Co., Philadelphia, manufacturers of scientific instruments, died Dec. 12, 1946, in his 87th year. Dr. Thwing was an eminent physicist and the holder of numerous patents in the field of thermo-electricity. A graduate of Northwestern University and the University of Bonn, Germany, Dr. Thwing was active in the field of education prior to entering business. His early work was in the development of the electric light and wireless. He also formulated Thwing's law on capacity.

Companies

The *Reynolds Metals Co.* has acquired the $23,200,000 Newark, Ohio, aluminum rolling mill from War Assets Administration under lease with option to purchase. Reynolds now operates in 19 states. The plant will produce 10,000,000 lb. of aluminum blooms and 15,000,000 lb. of rods per month.

A thoroughly modern metallurgical service laboratory has been put into operation by *Ajax Electric Co., Inc.,* Philadelphia maker of electric salt bath furnaces. Here metallurgists and production men concerned with heat treating can obtain a direct comparison between salt bath treating and other methods for their particular applications—and at no charge. Equipment consists of 7 Ajax furnaces, quench, acid pickling and rinse tanks, drying oven.

HOW THE WROUGHT BRASS INDUSTRY CONSERVES METAL

No industry melting *commensurate tonnage of vital metal can quite match the brass mills for conservation and low melting losses. The savings of metal total millions of pounds; clearly the method they use is worth noting:**

Virtually all the brass mills in North America use the Ajax-Wyatt induction melting furnace, for it has the lowest metal losses in the field — less than 1% — with superior temperature control and unapproached economy of operation on high production schedules such as we have today.

The accepted melting tool in brass rolling mills throughout the world.

AJAX ELECTRIC FURNACE CORP.
1108 Frankford Avenue
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* UPWARDS OF 5 BILLION POUNDS ANNUALLY

THE AJAX WYATT INDUCTION MELTING FURNACE

ASSOCIATE COMPANIES: AJAX METAL COMPANY, *Non-Ferrous Ingot Metals and Alloys for Foundry Use*
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AJAX ELECTRIC COMPANY, INC., *The Ajax-Hultgren Electric Salt Bath Furnace*
AJAX ENGINEERING CORPORATION, *Ajax-Tama-Wyatt Aluminum Melting Induction Furnaces*

Master Hands on Intricate Jobs use

SHAWINIGAN CARBIDE

SHAWINIGAN
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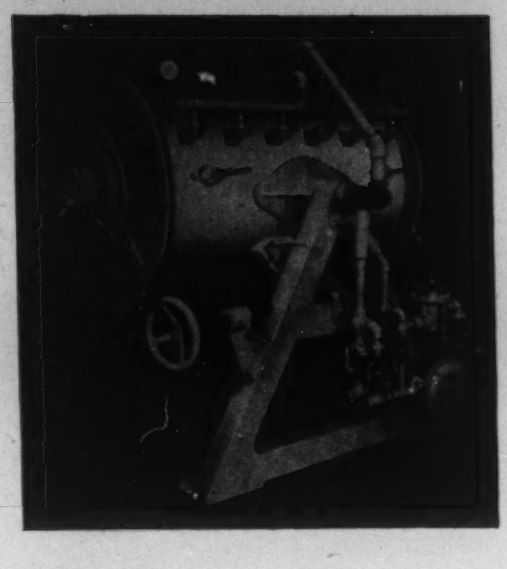
ROTARY GAS CARBURIZERS



Versatility is the outstanding characteristic of AGF Rotary Gas Carburizing Machines, which may be used not only for carburizing, but also for clean hardening, normalizing, annealing, and other general or atmospheric work without modification to the machine of any kind.

Uniform heating of the work is assured by the gentle mixing produced by the rotary action of the retort, which is heated by numerous carefully distributed and balanced gas burners. Carburizing or atmosphere gas is introduced through a simply-designed, trouble-free connection.

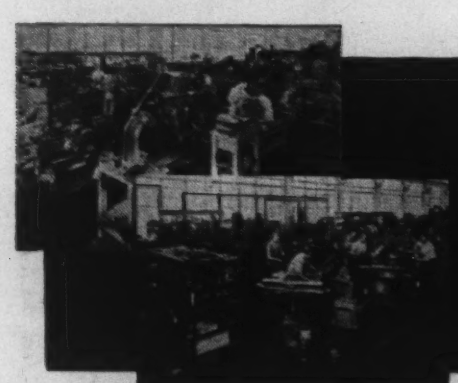
Charging and discharging of the work is accomplished by means of a tilting feature, which is power-driven on the larger models. The retort remains within the heat at all times.

The machine shown above is the latest, improved AGF Rotary Gas Carburizer, batch type, with new maintenance-free roller bearing retort support.

AGF gas carburizing equipment also includes Continuous Rotary Machines and Vertical Retort Carburizers. Write for literature.

American Gas Furnace Co.

Main Office and Works: Elizabeth, New Jersey



BOTWINIK
With Huge Rebuilding Facilities And Machine Stocks, Serves All Industry As Machinery Partner

3—Racine No. 30, capac. 10" x 10" Hydraulic Metal Cutting Saws, very late type.

Bradford 12" x 6' and Bradford 14" x 6' Lathes. (Brand new—in orig. crates.)

1—Amer. 24" x 12', 12 speed, Eng. Lathe, M.D., sw. over bed 27½", dist. betw. cens. 84".

Hendey 12" x 6' and 14" x 6', Yoke Hed., Tool Room Lathes, with taper attmts.

L. & S. 16" x 6', 20" x 8', 12 speed, grd. hed., Eng. Lathes.

1—Bridgeford 36" x 56', 15 speed, grd. hed., Eng. Lathes, M.D., AC elect. equip., power rap. trav. to carr., compound rest, 2 steady rests, sw. over bed 38", sw. over carr. 26", dist. betw. cens. 48'.

2—W. & S. No. 3, Univ. Turret Lathes, very latest type, used only 4 mos.—lg. asstmt. of tools.

2—W. & S. No. 4 Univ. Turret Lathes, very latest type, pre-select. hed., hole thru spin. 2 7/16".

W. & S. No. 1A (2) and 2A Turret Lathes, timk. bear., cov. ways, hole thru spins. 2 7/16".

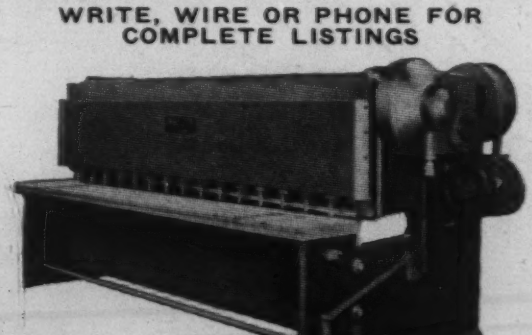
1—Cin.-ACME No. 1 Semi-Univ. Turret Lathe, M.D., timk. bear., arr. for chuck., bar capac. 2½", max. lgth. turn. 29", sw. over bed 20¾".

1—Gisholt No. 3R Turret Lathe, very lat. type, with bar & chuck. equip., sw. over bed 28½", hole thru spin. 5¼", consid. extra tooling, new price, incl. extra equip. approx. $16,000—sell. price now $4,000.

1—J. & L. No. 5 Turret Lathe, very latest type, bar and chuck. equip., hole thru spin. 3".

1—Mattison Hyd. Surf. Grinder, with mag. chuck, 18" x 24" x 72", power raise and lower to vert. hed. New 1942, Cond. excel.

WRITE, WIRE OR PHONE FOR COMPLETE LISTINGS



NEW →

1—*New RAFTER Steel Squaring Shears, capac. ¼" x 10' and 5/16" x 12', 60 strokes per min., fcty. mtzd., V-Belt Range front gauge 45", back gauge 24", ram adjustment 11/16".*

The Plant That Answers 1001 Machine Tool Problems

BOTWINIK BROTHERS of MASS., INC.

17 Sherman St. Worcester 1, Mass.

News of... ENGINEERS COMPANIES SOCIETIES

Greenback Industries, Inc., Greenback, Tenn., is now in production on atomized metal powders for powder metallurgy applications, including aluminum, copper and tin.

Aro-Cast Corp. and *Precise Castings Corp., Div. of Cooper Alloy Foundry Co.*, Hillside, N. J., have combined facilities in new quarters. Both centrifugal and vacuum method castings are utilized.

Ben Posniak has opened a consulting engineering service at 2 Maple Place, Ossining, N. Y., dealing in general engineering and specialized services, including materials handling and aeronautical engineering.

The general offices and manufacturing facilities of *O'Neil-Irwin Mfg. Co.* have been moved to Lake City, Minn., for the manufacture of precision benders, brakes, shears and die-less duplicating equipment.

An $11,000,000 zinc refinery will be built in Chicoutimi County, Quebec, sponsored by American and Canadian interests. The company is called the *American Quebec Zinc Refinery Co. Ltd.* Sulfur will be an important by-product.

A $1,000,000 rehabilitation of the Kaiser aluminum reduction plant at Tacoma, Wash., will be completed in March, according to officials of *Permanente Metals Corp.* Work consists of relining pots and repairing machinery. The plant uses the Soderberg electrode system, which requires no carbon baking plant.

Consolidated Coppermines Corp. has bought a controlling interest in the *Titan Metal Mfg. Co.*, Bellefonte, Pa., maker of brass and bronze rods, welding alloys, brass and bronze forgings, brass pressure die castings, etc.

Loewy Construction Co. (Hydropress), New York, will build and erect a complete metal work and rolling mill installation for India. *W. S. Rockwell Co.*, Fairfield, Conn., will ship one pusher-type billet heating furnace, two continuous plate reheating furnaces and one continuous sheet annealing furnace to India for a large new brass and copper mill.

The *Independent Pneumatic Tool Co.*, Chicago, announces a $1,000,000 expansion of its main works at Aurora, Ill. The annex will provide 85,000 sq. ft. of additional floor space for production.

News of...

ENGINEERS
COMPANIES
SOCIETIES

Societies

The *American Iron & Steel Institute* ll hold its 55th general meeting in w York, May 21 and 22. For the t time the general meeting will nprise a two-day session. The tech- al meeting will be held May 21 at Hotel Pierre, while the general eting will be held May 22 at the aldorf-Astoria. At the first day's sion will be held a new feature, the Charles M. Schwab Memorial Lec- e" on a subject of general interest.

Delegates from every mineral-pro- cing nation are expected at the orld Conference on Mineral Re- urces at the Waldorf-Astoria, New ork, March 17-19. It will be held in nnection with the 75th anniversary the *American Institute of Mining & etallurgical Engineers*. A key topic ll be replenishment, if possible, of r depleted resources. Among the eakers will be Julius A. Krug, Secre- ry of the Interior. Discussion will volve iron, steel, coal, petroleum and onferrous metals.

Sponsored jointly by the *U. S. Army ir Forces* and the *Magnesium Assn.*, magnesium exhibit is being held at Wright Field, Dayton, Ohio, Feb. 18- 0. It consists of a comprehensive emonstration of present practices and test developments in magnesium chnology.

L. R. Milburn, electrical engineer, Great Lakes Steel Corp., has been lected president, *Association of Iron & Steel Engineers* for 1947.

The *American Foundrymen's Assn.*, onoring C. E. Hoyt for "his long and ighly valued service to the foundry ndustry and the association," has re- amed its foundation lecture the Charles Edgar Hoyt Annual Lecture." The A. F. A. has named H. M. St. John, uperintendent, Crane Co., Chicago, he 1947 annual lecture course com- mittee chairman. A. M. Fulton, vice president, Northern Malleable Iron Co., St. Paul, heads the executive and re- search committees of the malleable division.

The *National Assn. of Corrosion Engineers* will meet in the Palmer House, Chicago, April 7-10 and be addressed by Dr. Norman Hackerman, professor of chemistry, University of Texas, on "Mechanism of Inhibitor Action." There will be five technical sessions and an exhibition.

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What can these NEW INDIUM alloys do for you?

These alloys melt at 117° F. and higher. They have almost negligible shrinkage in solidifying—.0002" per inch.

Among actual and suggested uses are:

Ultra-Low Temperature Solders in delicate special instruments.

Low-Temperature Fuses — for Diathermy, Electrical and Refrigeration Applications.

Mechanical Safety Devices for protecting delicate machinery, etc., against operation at harmful elevated temperatures and for controlling processing.

As transfer medium for transferring surface detail from one surface to another, where a conductive negative reproduction is desired as a foundation for electro forming to obtain metallic duplicate of original surface. Can be cast or sprayed against human tissues or other fragile materials without harm.

Joining of laboratory glassware for vacuum or pressure seal.

Many other applications. Describe your problem. Maybe we can give you the answer.

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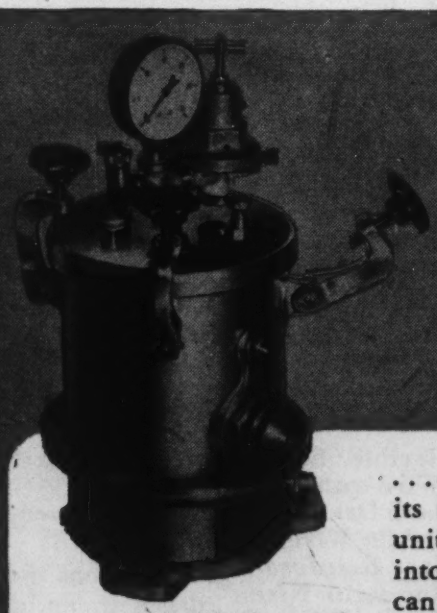

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. . . acclaimed as the finest machine of its kind. A versatile, precision-made unit, ideally adapted to wax injection into both rubber *and* metal molds . . . can be used as either a hydraulic or air-pressure operated unit.

WATCH FOR THE
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MOLD KIT
coming soon!

Check these features against any other wax injector on the market:

- Hydraulic or air-pressure operation
- Positive temperature control to within two degrees
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- Complete control over the quantity of wax injected
- Complete visibility of temperature and pressure at all times
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precision casting sales and engineering

P O T P

The "Proof of the Pudding" that Amersil's new engineering service pays off in practice, in large or small plants, having problems involving extreme temperatures and highly corrosive operating conditions is illustrated by the case histories shown.

ANNEALED SILICA TRAYS LASTS *a minimum of* 10 TIMES LONGER

*Name on request.

Ask an Amersil engineer to explain the new integrated engineering service which includes development, research, design, controlled manufacture of major silica ware units, selection and purchase of auxiliaries—all under one contract one responsibility.

60 TON PLANT

2½ TONS OF 22° B'e ACID AN HOUR ON A 24 HOUR BASIS DESIGNED BY AMERSIL

AMERSIL COMPANY Inc.

CHESTNUT AVENUE ENGELHARD HILLSIDE 5, N. J.

Aircraft Wire—tinned or alloy coated and galvanized
Armature Binding Wire—tinned or alloy coated
Belt Hook Wire—tinned, galvanized or alloy coated
Bobby Pin Wire
Brush Wire—round scratch brush, tempered and untempered. High strain white liquor finish
Card Wire—tempered, round, angular, single convex, double convex
Curtain Spring Wire—round, flat
Fish Leader Wire
Flexible Shaft Wire—Music Wire quality
Hard Drawn Spring Wire
Heddle Wire
Hose Reinforcement Wire
Mandolin Wire
Music Wire, bright, tinned or alloy coated
Piano Wire, perfected quality
Rope Wire, bright or galvanized—mild plow, plow, improved plow
Seal Wire
Stainless Steel Wire
Stapling Wire
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News of...

ENGINEERS COMPANIES SOCIETIES

Dr. Vannevar Bush, president, Carnegie Institution of Washington and wartime director of *Office of Scientific Research & Development*, has been named 1946 winner of the Hoover medal, jointly awarded by four national engineering societies. The medal is deemed one of the outstanding honors of the engineering profession.

Discussion sessions on metallurgy of power plants, industrial electronics and railroad power units will be added to the program of the ninth annual meeting of the *Midwest Power Conference*, March 31-April 2 at the Palmer House, Chicago.

The *American Institute of Mining & Metallurgical Engineers* has awarded the Anthony F. Lucas gold medal for 1947 to Dr. William Noble Lacey, dean of graduate studies at California Institute of Technology and consultant for several corporations. His work has been allied with the petroleum industry.

Meetings and Expositions

AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS, annual meeting. New York, N. Y. February 16-20, 1947.

AMERICAN SOCIETY FOR TESTING MATERIALS, Committee Week. Philadelphia, Pa. February 24-28, 1947.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, spring meeting. Tulsa, Okla. March 2-5, 1947.

AMERICAN GAS ASSOCIATION, industrial and commercial gas conference. Boston, Mass. March 17-19, 1947.

AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS, world conference on mineral resources. March 17-19, 1947.

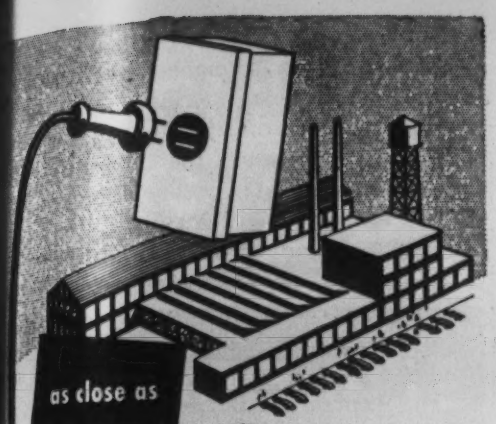
AMERICAN SOCIETY OF LUBRICATION ENGINEERS, annual meeting. Pittsburgh, Pa. March 17-19, 1947.

AMERICAN SOCIETY OF TOOL ENGINEERS, annual convention. Houston, Texas. March 19-22, 1947.

AMERICAN SOCIETY FOR METALS, Western metal congress and exposition. San Francisco, Calif. March 22-27, 1947.

SAFETY CONVENTION AND EXPOSITION, annual meeting. New York, N. Y. March 25-28, 1947.

MIDWEST POWER CONFERENCE. Chicago, Ill. March 31-April 2, 1947.



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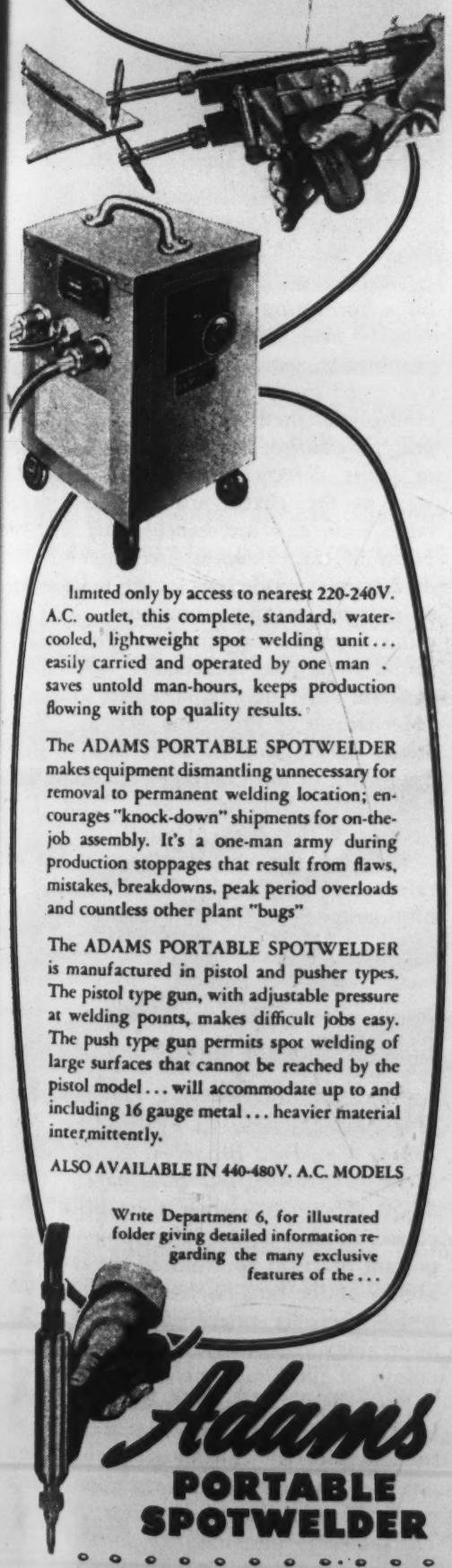
Adams PORTABLE SPOTWELDER



limited only by access to nearest 220-240V. A.C. outlet, this complete, standard, water-cooled, lightweight spot welding unit . . . easily carried and operated by one man . saves untold man-hours, keeps production flowing with top quality results.

The ADAMS PORTABLE SPOTWELDER makes equipment dismantling unnecessary for removal to permanent welding location; encourages "knock-down" shipments for on-the-job assembly. It's a one-man army during production stoppages that result from flaws, mistakes, breakdowns, peak period overloads and countless other plant "bugs"

The ADAMS PORTABLE SPOTWELDER is manufactured in pistol and pusher types. The pistol type gun, with adjustable pressure at welding points, makes difficult jobs easy. The push type gun permits spot welding of large surfaces that cannot be reached by the pistol model . . . will accommodate up to and including 16 gauge metal . . . heavier material intermittently.

ALSO AVAILABLE IN 440-480V. A.C. MODELS

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BOOK REVIEWS

A Russian Book on Steel Metallurgy

METALLURGY AND HEAT TREATMENT OF STEEL. *By N. F. Bolhovitinov. Published by The State Scientific & Technical Publishing House for Literature on Ferrous and Nonferrous Metallurgy, Moscow, U.S.S.R., 1946. Fabrikoid, 6 x 9 in., 319 pages. Price 25 rubles. (In Russian.)*

The title of this book is rather misleading, since it covers cast iron and some nonferrous alloys as well as steel. The main aim of the author was to present both the theory of metallurgy and its practical application to heat treating in a form that would help engineers in their work and enable them to make the widest possible use of comparatively inexpensive, low alloy materials. The secondary purpose was to describe new theories and processes as illustrated by practical examples from the automotive and tractor industries. Dr. Bolhovitinov succeeds admirably in giving a modern view of metallurgy that is well suited to engineers and can also serve as a textbook for a short course in metallurgy.

The broad subjects covered are: physico-chemical fundamentals of metallurgy, theory of alloys, iron-carbon alloys, carbon steels, cast iron, heat treatment of steel, chemico-thermal treatments (carburizing, nitriding, cyaniding and aluminizing), alloy machinery steels, use and heat treatment of alloy machinery steels, tool steels, steels with special physical and chemical properties (including stainless and heat resisting steels), nonferrous alloys (copper, aluminum, magnesium, Babbitt and die casting alloys), and methods of testing metals. Particular emphasis is paid to recent developments such as hardenability tests, S curves and their practical application, surface hardening, high strength cast irons, intensifiers such as boron, Tukon hardness tester and cyclograph.

The section on the use and heat treatment of alloy machinery steels seems to be especially well handled. Instead of the usual long and confusing lists of applications and general heat treatment temperatures, the author has taken a few specific parts, such as automotive gears, and has dealt in detail with the selection of steel, heat treatment cycles and possible defects. Throughout the book, the theoretical background is well coordinated with the practical application of these principles.

(Continued on page 162)

Here's A Money-Saving Lubricant For Metal-Forming

WHEN forming metal, your lubricating medium can save money for you if it maintains the fine balance between adequate viscosity and ease of removal. Oakite Stamping and Cutting Paste more than fits the bill! Water-emulsifiable and non-pigmented, its economical dilutions reduce rejects, extend die life, lower the cost of alkaline or solvent-type cleaning.

Applications

Wide variety of stamping, drawing, forming and blanking operations on copper, brass, steel and aluminum.

Cost Advantages

Minimizes breakage and replacement of dies . . . can be removed easily and quickly before soldering, welding, painting or phosphating . . . saves metal and improves surfaces of formed sheets or parts.

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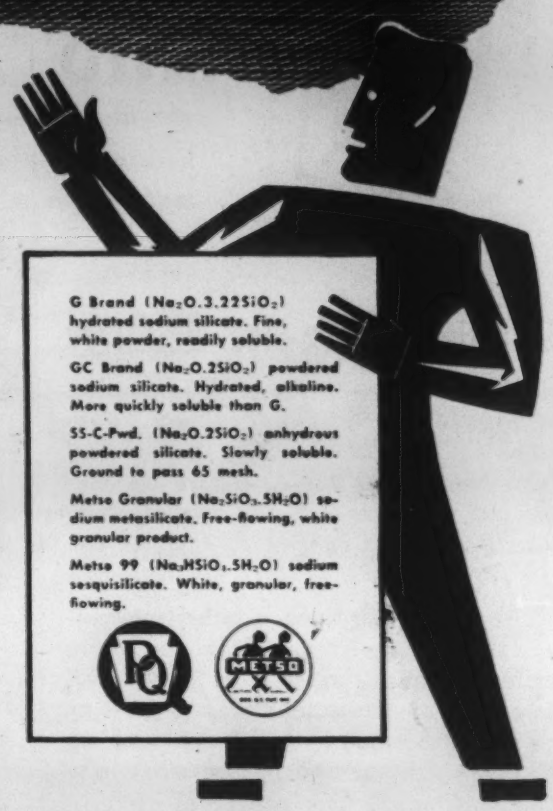
G Brand ($Na_2O.3.22SiO_2$) hydrated sodium silicate. Fine, white powder, readily soluble.
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Of interest to foreigners is the information on Russian specifications as well as the remarks on the reasons for the differences between the Russian and U.S.A. practice. The many references to U.S.A. research and plant practice, as well as the inclusion of A.I.S.I.-S.A.E. designations, A.S.T.M. grain size and graphite distribution charts show no lack of credit to metallurgical developments in this country.

The general bibliography in the back of the book is well chosen and completely up-to-date. However, one drawback of the book is the lack of detailed references throughout the text. Since only the author's name is given in each case, it would be difficult for anyone to check the original references if further information were desired.

—J. Z. Briggs

Galvanizing

GALVANIZING HANDBOOK. *By J. R. Doesen. Published by Reinhold Publishing Corp., New York, 1946. Cloth 7¼ x 10¼ in., 166 pages. Price $5.25.* Based on a consulting practice in a wide and varied field, this handbook presents graphically some of the basic principles concerned with both the hot dip and electrolytic methods of coating. Photographic examples of the nature and cause of many defects are included. These as well as the charts are presented on a large scale and are hence easily studied. Many of the examples used were articles deliberately spoiled so as to indicate, in an extreme manner, conditions which are difficult to illustrate in the degree usually found in regular practice.

Some of the 12 chapters include: "Mechanism of Protective Action," "Variations in the Iron or Steel Base," "Heat Treatment of the Coating," "Cleaning and Pickling," "Fluxing," and "Hot Dip Coating with Other Metals."

Most of the chapters have a list of references appended. There is also a bibliography on "Hot Tinning."

Not-so-Common Metals

RARER METALS. *By Jack De Ment and H. C. Dake. Published by Chemical Publishing Co., Inc., Brooklyn, N. Y., 1946. Cloth, 5½ x 8½ in., 392 pages. Price $7.50.* About 20 elements are briefly discussed in this book. Interesting and important practical applications are included. Metals of the rare earths are excluded on which there is extensive literature. The mineralogy, chemistry, physics and technology of these rare metals are described.

Basic data on rarer metals are correlated for the busy professional man and student. Special consideration has been given to the rarer elements upon which much of our future progress depends. The book is described as suitable as a reference text or for supplementary reading in science and engineering courses.

(Continued on page 163)

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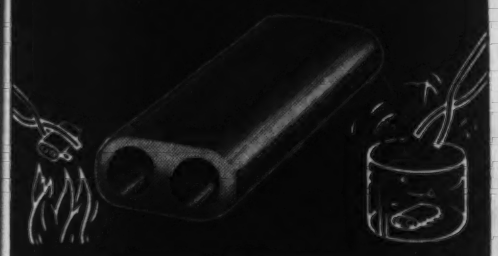

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There is a foreword by Dr. Colin G. Fink of Columbia University.

Each chapter has a list of references. There is an up-to-date bibliography, good illustrations and a detailed index.

Other New Books

MECHANICAL MEASUREMENTS BY ELECTRICAL METHODS. *By Howard C. Roberts. Published by The Instruments Publishing Co., Inc., Pittsburgh, 1946. Cloth, 4¾ x 8¼ in., 357 pages. Price $3.00.* Described as the only book on the increasingly important field of measurements commonly termed "electric gaging." In detail the author discusses: (1) all the methods for electrically measuring displacements, pressure vibrations, strains, accelerations, etc., and (2) most of the instruments and auxiliary equipment.

DEFINITION AND MEASUREMENT OF GLOSS. *By V. G. W. Harrison. Published by The Printing and Allied Trades Research Assoc., London, England, 1945. Cloth, 6½ x 9½ in., 145 pages. Price 10/.* This publication is a critical survey of published literature in the field of surface finish or gloss as a physical mechanism.

SYMPOSIUM ON MATERIALS FOR GAS TURBINES. *Published by American Society for Testing Materials, Philadelphia, Pa., 1946. Paper, 6 x 9 in., 199 pages. Price $3.00.* There are five extensive technical papers and three others on related subjects in this symposium dealing with high temperature materials which were not only of strategic importance in the war effort, but which are of great significance in peacetime industry.

THE PLASTICS INDUSTRY. *By Barrett L. Crandall, Published by Belman Publishing Co., Inc., Boston, Mass., 1946. Paper, 6 x 9 in., 36 pages. Price $1.00.* This is the first one of a series of American Industries Monographs whose purpose is to supply not only overall pictures of 75 basic American industries, but also to furnish specialized information about the "jobs" that comprise these industries. Special attention is called by the publishers to an Analytical Index of Occupations, which is especially designed to assist in locating easily the information about "jobs." The author, Mr. Crandall, is a former director of public relations, The Society of the Plastics Industry, New York.

BEST'S SAFETY DIRECTORY—1946-1947 EDITION. *Published by Alfred M. Best Co., Inc., New York, 1946. Fabrikoid, 8½ x 11¼ in., 351 pages. Price $5.00.* For the first time, in one volume, this directory presents an "encyclopedia" covering essential information on over 1000 products, devices and equipment used in safety, first aid, hygiene, health conservation, and fire protection. It tells briefly what safety product to use, when to use it, how to use it, and where to get it, thus tending to prevent many accidents. It is cross-indexed and contains a comprehensive topical index. It has been compiled and edited by the same men who have made the "Safety Engineering" magazine a leading publication in this field.

ENGLISH-FRENCH AND FRENCH-ENGLISH TECHNICAL DICTIONARY. *By Francis Cusset. Published by Chemical Publishing Co., Inc., Brooklyn, N. Y., 1946. Cloth, 5¼ x 6¾ in., 590 pages. Price $5.00.* To help the technical man to read technical texts this handy volume has been compiled. Students, librarians and translators will find it especially useful and it can be of help to other readers of French scientific works, for it covers many fields. The English equivalent of French terms and the French equivalent of English expressions have been "chosen with great competency and accuracy." This dictionary should be in every technical library.

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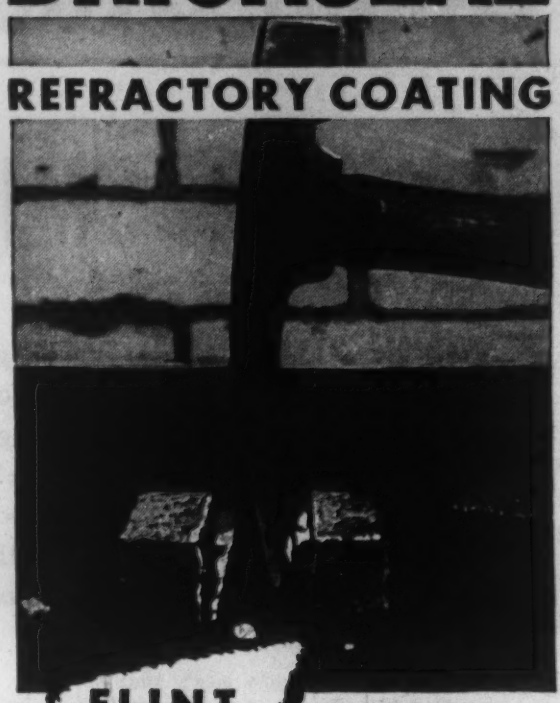

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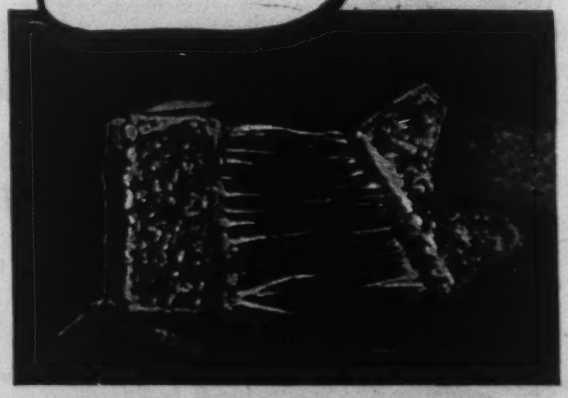

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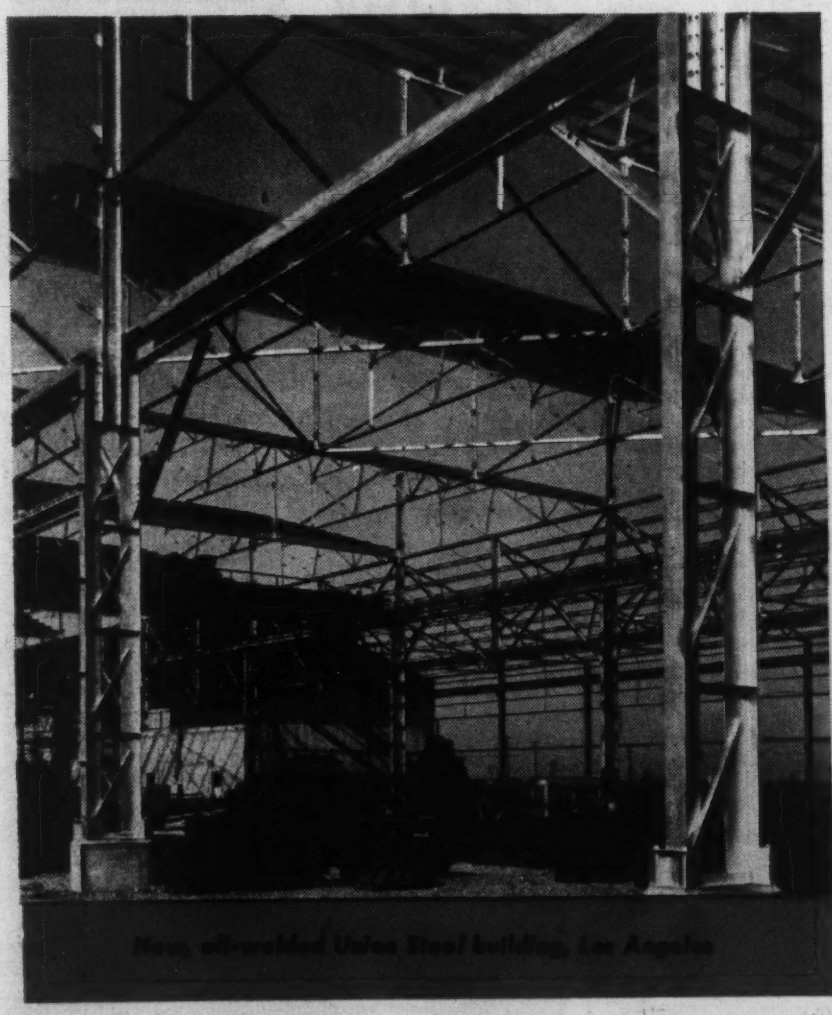

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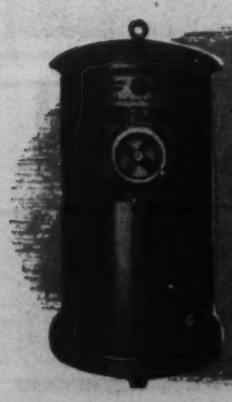

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The Last WORD

by T. C. DU MOND

What is an Editor

We're not sure we like it, but here is the latest definition of an industrial publication editor:

"He is like the eunuch in a harem.
He is right in the center of activity,
He sees and reports on what goes
on, but,
He can do very little about it."

No Longer Synthetic

As far as one rubber company is concerned we will hear no more about synthetic rubbers. Not that they are to abandon this field, it's only that they feel the term synthetic has many nasty connotations. "Synthetic," they say, "denotes inferiority to natural rubber." It's not true, in some cases s.....s are better. Henceforth please call them American rubbers.

Dry Cleaning Engineers

It is highly probable that some dry cleaning establishments have engineers of certain types, but now it would seem that they could use materials engineers. There seems to be a little difficulty in some dry cleaning shops because of the synthetic (there goes that word again) materials being used for linings, buttons and other parts of garments. Improper application of some of these materials by garment manufacturers has threatened to destroy the reputations of all plastics and fabrics so used. The National Association Institute of Dyeing & Cleaning, Inc., is testing many materials to see if they are suited to the dry cleaning process. Upon reflection, it may be the garment people that need materials engineers.

Margin of Error

It will always be a mystery to us as to how errors creep into technical articles in magazines like ours. It's probably even more of a mystery to you. Our wonderment results from a summary of how many times an article is read between the stage where the author kisses it a fond goodbye and the reader embraces it with wide-opened eyes. Each article gets read here in the shop at least seven times, somewhat as follows: At least twice by editors when it is read for acceptance; one or more times when it is edited; two complete proof-readings, and two more readings by the editors. Our only explanation is that our familiarity with that particular bit of wisdom almost reaches the contempt stage after the fifth or sixth reading.

A New Source of Scrap

Any of you readers happen to be dairymen or gentlemen farmers on the side? If so, don't overlook a source of much needed scrap that seems to have been overlooked in the past. It seems that recently a farmer slaughtered one of his cows and found about four pounds of steel in the bovine's stomach. There must have been considerable iron in the water on that farm. A pun comes to mind about milking this source, but with marvelous restraint we keep from inflicting it upon you.

Special Delivery Answer

We are glad to see, in this era of hasty conclusions and radical theories, that a bit of sober conservatism still remains. What is this bright star of hope? Well, one of the recent mails brought us an answer to a questionnaire on the use of alloy steels. The answers were all in order and reasonable. The only thing out of the way is that the results of this particular survey were published in our August 1945 issue. Twenty months is a long time to make up one's mind, even for a politician.

Iron Paving Blocks

Perhaps one of the reasons for the boast: "There will always be an England" is the knowledge that one section of London has cast iron streets. Several years ago a street was "paved" with hand-cast iron blocks. From all reports, the iron blocks are highly satisfactory, being quiet, easily laid and long lived. The chief reason such blocks were not used extensively is their high cost. If one of you high-production-minded individuals finds the answer to cheap output, your fortune is waiting.

Another Alibi Shattered

It's nice that business and pleasure can be mixed to their mutual benefit. We're now thinking about the recent development in golf club manufacture whereby, through broaching the irons, exact weights are achieved. It's nice that technical progress makes it possible to hold the weight of all clubs to within 1/16 oz. of all others, but it sure raises cain with one of our pet alibis. Now if they could only eliminate the splits in bowling.

Coals to Newcastle

It's improbable that Mr. Joseph F. Brush of Brooklyn needs a model of a plating barrel to remind him of his many years in the electroplating business. However, he is undoubtedly proud of the gold-plated model presented to him at a recent dinner of the Masters' Electroplating Association of New York in honor of his many years in the business. Maybe with this model Mr. Brush can continue plating as a hobby when and if he retires from active business.

Voluntary Rationing

Beer in cans is coming back. Several of the can manufacturing companies have broadcast that phrase for some time, in the hopes that sheet steel would be readily available. Now that an appraisal shows sheet steel supplies to be insufficient, this prediction is the clouded crystal ball type. However, the American Can Co. is helping to see that all industries—beer, food, petroleum and others—get their proportionate share of cans through a voluntary system of rationing that is more realistic than the systems, in effect during the war. Perhaps other industries should take a lesson from this to insure all of their customers having a fair share of whatever output there is.

FINIS